Max-Sum

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Contents

Chapter 1

Main Page

1.1 Overview

This library provides an implementation of the max-sum algorithm in C++. For more details about the purpose and theory behind this algorithm, please see `http://eprints.soton.ac.uk/265159/`

The source code for this library can be dowloaded from `here`.

A pdf version of this documentation is also available `here`.

If you have any comments or suggestions about this library or its documentation, please let me know via the main `project website`.

1.2 Library Organisation

The contents of this library are organised into two namespaces:

- maxsum, which contains all functions and classes that form part the public interface to this library; and
- maxsum::util, which contains utility code that forms part of the library implementation.

Our intention here is that only functions and types that are of direct interest to third party developers should be located in the maxsum namespace. In contrast, those in the maxsum::util interface are not intended to form part of the public interface to the library, and so should only be of interest to developers who wish to extend or modify the library.

Of the classes in the maxsum namespace, three provide the bulk of the library's functionality, and should be of particular interest to anyone wishing to apply the max-sum algorithm:

- maxsum::DiscreteFunction, which is used to represent mathematical functions that depend on the cartesian product of a set of variables with finite domains;
- maxsum::DomainIterator, which provides methods for iterating over the domain of DiscreteFunction objects; and
- maxsum::MaxSumController, which operates on a *factor graph*, to optimise the values assigned to a set of (action) variables.

The following sections describe each of these classes in more detail, together with example extracts of code to demonstrate their proper use.

1.3 The DiscreteFunction Class

The DiscreteFunction class is the main workhorse of the maxsum library, which not only provides a way to represent mathematical functions, but also to manipulate their values, and combine them using various mathematical operators to form new functions. As the class name suggests, the main limitation is that only functions with a finite domain can be represented, values of which are stored internally for each possible value of a function's domain.

In future versions, we may provide other classes which can be used to represent functions with continuous domains. However, for now, the DiscreteFunction class provides all the operations necessary to apply the max-sum algorithm to finite domains. In particular, the following subsections describe the main operations that can be performed using this class.

1.3.1 Construction

The domain of each DiscreteFunction is specified by a set of variables, identified by ids of type maxsum::VarID. Each variables, `k`, is associated with a fixed domain size, N_k, which must be registered before the variable is used, and must remain the same through a program's execution. Once registered, a variable can then take on any integer value in the range $[0, N_k]$. For example, to create a DiscreteFunction that depends on a single variable, `2`, we may execute the following code:

```
maxsum::registerVariable (2, 10);
maxsum::DiscreteFunction func(2,3.2);
```

Here, variable `2` is registered with domain size `10`, which means that it can take on values in the range $[0,9]$. The 2nd parameter of this constructor is used to initialise all values for this function to a specific value, in this case 3.2. So, for example, we have

```
num = func.noVars(); // num == 1 (depends on one variable only)
siz = func.domainSize(); // siz == 10
val = func(0);  // val == 3.2
...
val = func(9);  // val == 3.2
val = func(10); // result undefined!!
```

In addition to depending on a single value, DiscreteFunction's can also depend on multiple variables, or the empty set. In the latter, case the function encapsulates a single scalar constant, which does not depend on any variable, and is index by 0:

```
maxsum::DiscreteFunction func(4.5); // depends on no variables
num = func.noVars();     // num==0 (depends on no variables)
siz = func.domainSize(); // siz==1 (has only one value)
val = func(0); // val == 4.5
val = func(1); // result undefined!!
```

For the former case, there are several options for defining functions that depend on several variables. In particular, we can achieve this by passing a list of variable ids to the constructor using iterators. For example:

```
maxsum::VarID vars[] = {1,4,8}; // array of size 3
maxsum::ValIndex siz[] = {5,10,15}; // var 1 has domain size 5 etc.
maxsum::registerVariables (vars,vars+3,siz,size+3);
maxsum::DiscreteFunction func(vars,vars+3); // values initialised to 0
num = func.noVars(); // num=3 (depends on three variables)
siz = func.domainSize(); // siz=5*10*15 (size of cartesian product)
val = func(0);   // val == 0
val = func(749); // val == 0 (see below for full explanation)
val = func(750); // result undefined!!
```

In addition to these, other constructors include a copy constructor and matching assignment operator; and a default constructor, which creates a function that depends on no variables and has a single value of 0. For details, see the manual page for DiscreteFunction.

1.3.2 Element Access

As demonstrated in the examples above, the basic and most efficient way to access the values of a function, is to pass a single integer value to the overloaded () operator. This single integer value acts like a linear index for N-D arrays in matlab, except that values start from 0 rather than 1. Moreover, all versions of the () operator return references to values in a DiscreteFunction, and so can be used for setting as well as reading values. For example, the following code is valid.

```
func(1) = 3.45; // set func(1) to 3.45
val = func(1);  // val == 3.45
```

As in matlab, or indeed any scheme for indexing N-D arrays, these linear indices depend on the order in which each dimension is stored in memory. In our case, each variable in a function's domain corresponds to a dimension in an N-D array, with variables ordered from least to most significant according to their ID. For example, if `func` depends on variables 3 and 5 with corresponding domain sizes 2 and 3, then we have the following correspondence between variable values and linear indices:

Variable 3	Variable 5	Linear Index
0	0	0
1	0	1
0	1	2
1	1	3
0	2	4
1	2	5

Here, notice how variable 3, having the smalled variable id, is incremented first, before the variable with the next largest id, which is 5. The situation is the same for variables with more than two variables: the variable with the smallest id is incremented first, and so on until the variable with the highest id, which is incremented last.

Although the most efficient way to access elements using linear indices, these are often not available, and so must be calculated from a set of subindices, relating to named variables. For this reason, several other versions of the () operator are available that except subindices. For example, if variable names and values are stored in lists, s.t. the kth index gives the value for the kth variable, then we can access elements as follows.

```
maxsum::VarID vars[] = {1,4,8}; // array of size 3
maxsum::ValIndex siz[] = {5,10,15}; // var 1 has domain size 5 etc.
maxsum::registerVariables (vars,vars+3,siz,size+3);
maxsum::DiscreteFunction func(vars,vars+3); // values initialised to 0

std::vector<VarID> varVec(vars,vars+3); // copy ids into vector
std::vector<ValIndex> valVec(3); // vector of size 3
valVec[0] = 2; // index value for variable 1
valVec[1] = 4; // index value for variable 4
valVec[2] = 5; // index value for variable 8

 // THE FOLLOWING STATEMENTS ALL ACCESS THE SAME ELEMENT
int linearIndex = 2+4*10+5*15*10; // corresponding linear index
func(2,4,5); // specify indices in order of variable id
func(valVec.begin(),valVec.end()); // indices in order of variable id
func(linearIndex); // access by corresponding linear index
func(varVec,valVec); // access by named variables in lists (does not work for arrays)
func(vars,vars+3,valVec.begin(),valVec.end()); // access by named variables using iterators
func(varVec.begin(),varVec.end(),valVec.begin(),valVec.end());
```

Here, the last three variants all work by specifying named variables and corresponding values in lists, either by passing reference to containers directly (which must supply interfaces consistent with standard library containers), or by passing iterators to such lists. In each case, the kth value is assumed to correspond to the kth named variable. Any values specified for variables that are not in the functions domain are ignored.

For some versions of the () operator, the member function maxsum::DiscreteFunction::at is also provided for convenient element access through pointers. For example, the following code is valid:

```
using namespace maxsum;
```

```
registerVariable (3,5);
DiscreteFunction func(3,4.5);
DiscreteFunction* pFunc = &func;
val = (*pFunc)(2);  // works, but ugly
val = pFunc->at(2); // equivalent, but more readable
```

1.3.3 Mathematical Operations

Three main types of mathematical operation are provided by the maxsum::DiscreteFunction class, each of which are described below.

1.3.3.1 Scalar Operations

Scalar operations are used to calculate specific statistics about a function's values over its domain. The table below summarises the available scalar operations, together with their mathematical definition w.r.t. a maxsum::DiscreteFunction, f, with linear indices 1 to N.

Member Function	**Definition**
DiscreteFunction::mean	$\frac{1}{N}\sum_{k=1}^{N} f(k)$
DiscreteFunction::max	$\max_k f(k)$
DiscreteFunction::min	$\min_k f(k)$
DiscreteFunction::maxnorm	$\max_k \lvert f(k) \rvert$

1.3.3.2 Domain Operations

Domain operations operate on a single DiscreteFunction object to reduce or expand its domain in some way. In particular, the DiscreteFunction::expand member extends the set of variables that a DiscreteFunction depends on, such that its new domain is the union of its previous domain, and a set of variables specified by the expand function's arguments. Several overloaded versions exist that allow the new set of variables to be specified in different ways:

Member Function	**Description**
DiscreteFunction::expand(const VarID var)	Expands the domain to include the variable `var`.
DiscreteFunction::expand(const DiscreteFunction& fun)	Expands the domain of `this` DiscreteFunction to include all variables in the domain of `fun`.
template<class VarInd> DiscreteFunction::expand(VarInd begin,VarInd end)	Expands the domain to include all variables in the sequence pointed to by the iterators `begin` and `end`.

After a call to `expand`, the DiscreteFunction's values remain the same for all elements of its previous domain. For example

```
using namespace maxsum;
registerVariable (1,3);
registerVariable (2,3);
DiscreteFunction func(2,0); // depends only on variable 2
func(0) = 1.1;
func(1) = 2.2;
func(2) = 3.3;

func.expand(1);    // func now depends on variables 1 and 2
val = func(1,0);   // val == 1.1
val = func(2,0);   // val == 1.1
val = func(1,2);   // val == 3.3
val = func(2,2);   // val == 3.3
```

As well as expanding a DiscreteFunction's domain, it is often necessary to *reduce* its domain. In general, this results in a loss of information, so it is necessary to specify how the values in the new smaller domain are derived from those in the original larger domain. Currently, there are two ways to do this.

First, the DiscreteFunction::condition member function can be used to specify fixed values for a set of variables that are to be removed from a function's domain. For example, following on from the code in the last example, we may may reduce the domain of `func` as follows.

```
VarID toRemove[] = {2}; // list of variables to remove
ValIndex vals[] = {1};   // fixed values for removed variables
func.condition (toRemove,toRemove+1,vals,vals+1); // specify iterators over arrays

val = func(0); // val == 2.2 (because variable 2 was given fixed value 1)
val = func(1); // val == 2.2 (see code above)
val = func(2); // val == 2.2
```

Second, rather than conditioning on specific values for the removed removed variables, we can *marginalise* by somehow aggregating all the values for the removed variables to produce a single value. In particular, the definition of the max-sum algorithm requires variables to be removed by taking a function's maximum value across the removed variables. Here, this is achieved using the maxMarginal function, which takes the maximum value of one DiscreteFunction across a set variables, and stores the result in another DiscreteFunction.

This works by passing references to two DiscreteFunctions: the first, `inFun`, is the original function to be marginalised, and the second, `outFun`, is a function with a smaller domain, in which the result will be stored. The domain of `outFun` must not be larger than the domain of `inFun`, and any variables that are in the domain of `inFun`, but not in the domain of `outFun`, will be marginalised. This procedure is demonstrated in the following code.

```
VarID vars = {1,2};
ValIndex siz = {2,3}; // variable 1 has domain size 2, etc.
registerVariables (vars,vars+2,siz,siz+2);
DiscreteFunction inFun(vars,vars+2);  // depends on variables 1 and 2
DiscreteFunction outFun(vars,vars+1); // depends on variable 1 only

inFun(0,0) = 1; // assign some values to inFun
inFun(1,1) = 2;
inFun(0,2) = 3;
inFun(1,0) = 4;
inFun(0,1) = 5;
inFun(1,2) = 6;

maxMarginal (inFun,outFun); // max marginalise inFun and store result in outFun

val = outFun(0);  // val==5 (maximum value for variable 1=0 in inFun)
val = outFun(1);  // val==6 (maximum value for variable 1=1 in inFun)
```

The reason for this style is efficiency: by preallocating `outFun` to store the result, we do not need to not need to allocate temporary objects in memory, and if necessary, can reuse `outFun` to store the result of several similar marginalisations.

More generally, the maxsum library also provides a number marginalisation functions, which aggregate across the removed variables in different ways. These are summarised in the table below. However, only the maxMarginal function is actually required to implement the max-sum algorithm. See `The MaxSumController Class` for details.

Function	Description
maxMarginal	Marginalise by maximising across removed variables.
minMarginal	Marginalise by minimising across removed variables.
meanMarginal	Marginalise by averaging across removed variables.
marginal	Marginalise using a custom aggregation function.

1.3.3.3 Arithmetic Operations

Arithmetic operations on DiscreteFunction's are provided by overloading the standardard arithmetic operators in C++, including $+$, $-$, and $*$. These operations are applied elementwise across the cartesian product of the operands' domains, as illustrated in the following example:

```
VarID vars = {1,2};
ValIndex siz = {2,3}; // variable 1 has domain size 2, etc.
registerVariables (vars,vars+2,siz,siz+2);
DiscreteFunction f(vars,vars+1);   // depends only on variable 1
DiscreteFunction g(vars+1,vars+2); // depends only on variable 2
DiscreteFunction h(vars,vars+2);   // depends on variables 1 and 2

// assign some values
  f(0) = 1.0;   f(1) = 1.1;
  g(0) = 2.0;   g(1) = 2.1;   g(2) = 2.2;
h(0,0) = 3.0; h(0,1) = 3.1; h(0,2) = 3.2;
h(1,0) = 4.0; h(1,1) = 4.1; h(1,2) = 4.2;

DiscreteFunction x = f+g;
// x(0,0) == f(0) + g(0) == 1.0 + 2.0 == 3.0;
// x(1,0) == f(1) + g(0) == 1.1 + 2.0 == 3.1;
// ....
// x(1,2) == f(1) + g(2) == 1.1 + 2.2 == 3.3;

DiscreteFunction y = f+h;
// y(0,0) == f(0) + h(0,0) == 1.0 + 3.0 == 4.0;
// y(1,0) == f(1) + h(1,0) == 1.1 + 4.0 == 5.1;
// ....
// y(1,2) == f(1) + h(1,2) == 1.1 + 4.2 == 5.3;
```

Here, notice that the domain of the results, `x` and `y`, are automatically set to the cartesian product of the domains of the operands. The following operations are all similarly defined.

Operation	Description
`f + g`	Element-wise addition.
`f - g`	Element-wise subtraction.
`f * g`	Element-wise multiplication.
`f += g`	Element-wise addition, storing result in `f`.
`f -= g`	Element-wise subtraction, storing result in `f`.
`f *= g`	Element-wise multiplication, storing result in `f`.
`-g`	Unary Minus.

The right operand, `g`, can also be replaced by a scalar value of any numeric type convertable to ValType. In this case, the scalar is operated on with each element in the DiscreteFunction's domain e.g.

```
DiscreteFunction z = f + 100.5;
// z(0) == f(0) + 100.5 == 1.0 + 100.5 == 101.5
// z(1) == f(1) + 100.5 == 1.1 + 100.5 == 101.6
```

Since adding a number of DiscreteFunctions together is a common procedure, a member function DiscreteFunction::add is also provided, which takes iterators to the start and end of a sequence of DiscreteFunctions, and adds them all to the current DiscreteFunction, expanding its domain if necessary.

1.3.4 Comparison Operations

Equality between DiscreteFunctions can be defined in several ways, and for this reason the maxsum library provides three different functions for testing equality between DiscreteFunction objects:

Function	Description
sameDomain(const DiscreteFunction& f1, const DiscreteFunction& f2)	Returns true iff `f1` and `f2` have the same domain.
equalWithinTolerance(const DiscreteFunction& f1, const DiscreteFunction& f2, ValType tol)	Returns true iff `f1` and `f2` are equal across the cartesian product of their domains, within a given tolerance, `tol`.
strictlyEqualWithinTolerance(const DiscreteFunction& f1, const DiscreteFunction& f2, ValType tol)	Returns true iff `sameDomain(f1,f2) && equalWithinTolerance(f1,f2,tol)`

The functions equalWithinTolerance and strictlyEqualWithinTolerance are provided so that two DiscreteFunctions can be treated as equal in cases where their values differ only by some small rounding error. For cases in which strict equality is required between values is required (i.e. the error tolerance is 0), the standard equality and inequality operators may also be used:

Operator	Definition
`f1==f2`	`equalWithinTolerance(f1,f2,0)`
`f1!=f2`	`!equalWithinTolerance(f1,f2,0)`

1.3.5 Miscellaneous Operations

The DiscreteFunction class includes a number of members that do not directly relate to a DiscreteFunction's values, but instead provide meta data about the function, and enable various house keeping operations. These are summarised in the following table.

Function	Description
DiscreteFunction::domainSize	Returns the size of this DiscreteFunction's domain, defined as the product of the domain sizes for each variable in its domain.
DiscreteFunction::noVars	Returns the number of variables in this DiscreteFunction's domain.
DiscreteFunction::dependsOn	Returns `true` if a specified variable is in this DiscreteFunction's domain.
DiscreteFunction::varBegin	Returns an iterator to the start of the list of variables in this DiscreteFunction's domain.
DiscreteFunction::varEnd	Returns an iterator to the end of the list of variables in this DiscreteFunction's domain.
DiscreteFunction::sizeBegin	Returns an iterator to the start of a list of domain sizes, in which the kth element gives the domain size for the kth variable in this DiscreteFunction's domain.
DiscreteFunction::sizeEnd	Returns an iterator to the end of a list of domain sizes, in which the kth element gives the domain size for the kth variable in this DiscreteFunction's domain.

1.4 The DomainIterator Class

Todo.

1.5 The MaxSumController Class

MaxSumController is the main class responsible for implementing the max-sum algorithm, and providing its results. To run the algorithm using this class, the following steps are all that is required:

1. Register all variables in the factor graph using either registerVariable or registerVariables.
2. Create a set of DiscreteFunction objects, representing each factor in the target problem's factor graph.
3. Construct a new MaxSumController object, optionally specifying termination conditions.
4. Use the MaxSumController::setFactor member function to specify the set of factors from the previously created list of DiscreteFunction objects.
5. Call MaxSumController::optimise to run the max-sum algorithm
6. Use MaxSumController::valBegin and MaxSumController::valEnd to iterate through all variables in the factor graph, and retrieve there optimal values.

For example, the following code illustrates how these steps may be implemented in practice:

```
using namespace maxsum;
std::vector<VarID> vars; // list of variables in factor graph
std::vector<ValIndex> sizes; // sizes[k] == domain size for vars[k]
// ... populate above containers with appropriate values
registerVariables(vars.begin(),vars.end(),sizes.begin(),sizes.end());

std::map<FactorID,DiscreteFunction> factors; // factors mapped to ids
// populate factors with DiscreteFunctions mapped to factor ids

MaxSumController controller(100,0.0001); // new controller with custom stopping conditions
                                         // see MaxSumController::MaxSumController for details
// set up factor graph inside controller
// edges of graph are inferred automatically for factor domains
typedef std::map<FactorID,DiscreteFunction>::const_iterator Iterator;
for(Iterator it=factors.begin(); it!=factors.end(); ++it)
{
   controller.setFactor(it->first,it->second);
}

controller.optimise(); // run the max-sum algorithm

for(MaxSumController::ConstValueIterator it=controller.valBegin();
    it!=controller.valEnd(); ++it)
{
   std::cout << "Optimal value for variable " << it->first
             << " is " << it->second << std::endl;
}
```

In addition to these functions, MaxSumController class also provides a number of other member functions to set, change, and query the factor graph in different ways. These are particular useful in the problems were the factor values, or the shape of the factor graph can change over time. For further information, see the manual page for MaxSumController.

1.6 Tips on Writing Efficient Code

In general, the guidelines for writing efficient C++ code in any context also apply to code written using the maxsum library. In particular, one key piece of advice is to, as far as possible, avoid creating temporary objects in memory, when existing objects can be modified and reused.

One place where temporary objects are (currently) unavoidable is in the use of certain overloaded operators:

- The arithmetic operators, `+`, `-`, and `*` all create temporary objects to store their result
- The postfix increment operator, `++`, returns a copy of its operand, before incrementing the operands value.

We have plans to implement lazy evaluation, which would minimise the use of temporary objects, and improve performance in many instances. For now though, if you find you need more speed you may wish to consider the following *destructive* alternatives, which replace an operand's original value with the result:

Operation	Efficient Alternative
`it++`	`++it`
`f = f + g`	`f+=g`
`f = f - g`	`f-=g`
`f = f * g`	`f*=g`
`f = - f`	`f *= -1`

When performing arithmetic with DiscreteFunctions, another useful technique to expand a function's domain to its final size, rather than allowing its domain to change incrementally with each operation. For example, suppose DiscreteFunctions `f`, `g` and `h` depend on the single variables 1, 2, and 3 respectively. Now consider the following code.

```
// f starts with domain {1} only
f += g; // f reallocated to expand domain to {1,2}
f += h; // f reallocated to expand domain to {1,2,3}
```

On the otherhand, if we know the final domain in advance, we can improve efficiency by doing the following:

```
VarID vars[] = {1,2,3};
f.expand(vars,vars+3); // domain of f is now {1,2,3}
f += g; // more efficient: no domain change necessary
f += h;
```

1.7 Future Work

Although the basic implementation of this library is now complete, this project is still under going its first phase of active development. Accurate results are thus not yet guarranteed, and in fact, bugs are very much still to be expected.

For now, our main priority is thus continued testing and debugging. Beyond that, we also plan to look at various options for optimising the code and improving the interface. For example, one option is to link to the `eigen3` linear algebra library, to take advantage of its hardware vectorisation. We are also considering lazy evaluation as an option for optimising overloaded operators for the DiscreteFunction class.

We will also continue to improve this documentation of the API. All comments and feedback welcome!

Chapter 2

Namespace Index

2.1 Namespace List

Here is a list of all documented namespaces with brief descriptions:

Chapter 3

Hierarchical Index

3.1 Class Hierarchy

This inheritance list is sorted roughly, but not completely, alphabetically:

Chapter 4

Class Index

4.1 Class List

Here are the classes, structs, unions and interfaces with brief descriptions:

Chapter 5

File Index

5.1 File List

Here is a list of all documented files with brief descriptions:

Chapter 6

Namespace Documentation

6.1 maxsum Namespace Reference

Namespace for all public types and functions defined by the Max-Sum library.

Namespaces

- namespace util

  Utility namespace for types used for maxsum library implementation.

Classes

- class DiscreteFunction

  Class representing functions of sets of variables with discrete domains.
- class DomainIterator

  This class provides methods for iterating over the Cartesian product for a set of variable domains.
- class NoSuchElementException

  Exception thrown when there has been an attempt to access an element of a container that does not exist, and cannot be created on demand.
- class EmptyNoticeException

  Exception thrown by maxsum::util::PostOffice::popNotice when there are no active notices.
- class UnknownAddressException

  Exception thrown when a maxsum::util::PostOffice does not recognise the ID of a Sender or Receiver.
- class BadDomainException

  Exception thrown when subindices are incorrectly specified for a maxsum::DiscreteFunction.
- class OutOfRangeException

  Exception thrown when indices are out of range.
- class DomainConflictException

  Exception thrown when conflicting domains are specified for a variable.
- class UnknownVariableException

  Exception thrown when a variable is referred to, but has not yet been registered using either maxsum::registerVariable or maxsum::registerVariables.
- class InconsistentDomainException

  Exception thrown when variable domains are somehow registered as inconsistent.
- class MaxSumController

  This class maintains a factor graph and implements the max-sum algorithm.

Typedefs

- typedef double ValType

  Type of values stored by maxsum::DiscreteFunction objects.
- typedef unsigned int VarID

  Type used for uniquely identifying variables.
- typedef unsigned int FactorID

  Type used for uniquely identifying factors in a factor graph.
- typedef int ValIndex

  Integer type used for indexing coefficient values.
- typedef ValType(∗ UnaryScalarOp)(const ValType)

  Function type for operations applied to function values.
- typedef ValType(∗ DualScalarOp)(const ValType, const ValType)

  Function type for operations applied to two functions.

Functions

- template<class VecType >
  void ind2sub (const VecType &siz, const typename VecType::value_type ind, VecType &sub)

  C++ Implementation of Matlab ind2sub function.
- template<class SizIt , class SubIt >
  ValIndex sub2ind (SizIt sizFirst, SizIt sizEnd, SubIt subFirst, SubIt subEnd)

  C++ Implementation of Matlab sub2ind function.
- template<class VecType >
  VecType::value_type sub2ind (const VecType &siz, const VecType &sub)

  C++ Implementation of Matlab sub2ind function.
- std::ostream & operator<< (std::ostream &out, const DiscreteFunction &fun)

  Pretty prints a maxsum::DiscreteFunction Format is similar to the disp function in Matlab for N-D arrays, except that first dimension appears in rows rather than columns.
- bool sameDomain (const DiscreteFunction &f1, const DiscreteFunction &f2)

  Check that two maxsum::DiscreteFunction objects have the same domain.
- bool equalWithinTolerance (const DiscreteFunction &f1, const DiscreteFunction &f2, ValType tol=DEFAULT-_VALUE_TOLERANCE)

  Check that two maxsum::DiscreteFunction objects are equal within a specified tolerance.
- bool strictlyEqualWithinTolerance (const DiscreteFunction &f1, const DiscreteFunction &f2, ValType tol=DE-FAULT_VALUE_TOLERANCE)

  Check that two maxsum::DiscreteFunction objects are equal with a specified tolerance, and have exactly the same domain.
- bool operator== (const DiscreteFunction &f1, const DiscreteFunction &f2)

  Return true if functions are equal.
- bool operator!= (const DiscreteFunction &f1, const DiscreteFunction &f2)

  Return true if functions are equal.
- DiscreteFunction operator/ (const ValType f1, const DiscreteFunction &f2)

  Peforms element-wise division of a scalar by a function.
- DiscreteFunction operator∗ (const ValType f1, const DiscreteFunction &f2)

  Peforms element-wise multiplication of a scalar by a function.
- DiscreteFunction operator+ (const ValType f1, const DiscreteFunction &f2)

  Peforms element-wise addition of a scalar by a function.
- DiscreteFunction operator- (const ValType f1, const DiscreteFunction &f2)

  Peforms element-wise subtraction of a function from a scalar.

- template<class VarIt , class IndIt >
  void condition (const DiscreteFunction &inFun, DiscreteFunction &outFun, VarIt vBegin, VarIt vEnd, IndIt iBegin, IndIt iEnd)

  Condition function on specified variable values.
- template<class VarMap >
  void condition (const DiscreteFunction &inFun, DiscreteFunction &outFun, VarMap vars)

  Condition function on specified variable values.
- template<typename F >
  void marginal (const DiscreteFunction &inFun, F aggregate, DiscreteFunction &outFun)

  Marginalise a maxsum::DiscreteFunction using a specified aggregation function.
- void maxMarginal (const DiscreteFunction &inFun, DiscreteFunction &outFun)

  Marginalise a maxsum::DiscreteFunction by maximisation.
- void minMarginal (const DiscreteFunction &inFun, DiscreteFunction &outFun)

  Marginalise a maxsum::DiscreteFunction by minimisation.
- void meanMarginal (const DiscreteFunction &inFun, DiscreteFunction &outFun)

  Marginalise a maxsum::DiscreteFunction by averaging.
- template<UnaryScalarOp OP>
  DiscreteFunction elementWiseOp (const DiscreteFunction &inFcn)

  Template used to generate operations that apply some function to each of a DiscreteFunction's values.
- template<DualScalarOp OP>
  DiscreteFunction elementWiseOp (const DiscreteFunction &inFcn1, const DiscreteFunction &inFcn2)

  Template used to generate operations that apply some operation to a pair of DiscreteFunctions.
- std::ostream & operator<< (std::ostream &out, MaxSumController &controller)

  Utility function used to dump the current state of this controller for debugging purposes.
- bool isRegistered (VarID var)

  Returns true if the specified variable is registered.
- template<class VarIt >
  bool allRegistered (VarIt varBegin, VarIt varEnd)

  Returns true if all specified variables are registered.
- ValIndex getDomainSize (VarID var)

  Returns the registered domain size for a specified variable.
- int getNumOfRegisteredVariables ()

  Returns the number of currently registered variables.
- void registerVariable (VarID var, ValIndex siz)

  Registers a variable with a specified domain size.
- template<class VarIt , class IndIt >
  void registerVariables (VarIt varBegin, VarIt varEnd, IndIt sizBegin, IndIt sizEnd)

  Register a list of variables with specified domain sizes.

Variables

- const ValType DEFAULT_VALUE_TOLERANCE = DBL_EPSILON $*$ 1000.0

  Default tolerance used for comparing values of type maxsum::ValType.

6.1.1 Detailed Description

Namespace for all public types and functions defined by the Max-Sum library.

6.1.2 Typedef Documentation

6.1.2.1 typedef unsigned int **maxsum::FactorID**

Type used for uniquely identifying factors in a factor graph.

This is purposely an integer type, because we want this to be efficient for storing and passing between functions. Note: bitwise operations can be used in some addressing schemes, e.g. something like IP addresses.

See Also

maxsum::VarID

6.1.2.2 typedef int **maxsum::ValIndex**

Integer type used for indexing coefficient values.

This is the value type for all variables that are referenced an identified using maxsum::VarID. In particular, if a value of type maxsum::ValIndex is specified for each variable in a maxsum::DiscreteFunction object's domain, then exactly one value of type maxsum::ValType will be returned by element accessor functions, such as maxsum::-DiscreteFunction::at

6.1.2.3 typedef double **maxsum::ValType**

Type of values stored by maxsum::DiscreteFunction objects.

This is, this type is used to represent the codomain of mathematical functions represented by maxsum::Discrete-Function objects.

See Also

maxsum::DiscreteFunction

6.1.2.4 typedef unsigned int **maxsum::VarID**

Type used for uniquely identifying variables.

This is purposely an integer type, because we want this to be efficient for storing and passing between functions. Note: bitwise operations can be used in some addressing schemes, e.g. something like IP addresses.

See Also

maxsum::FactorID

6.1.3 Function Documentation

6.1.3.1 template$<$class VarIt $>$ bool maxsum::allRegistered (VarIt *varBegin,* VarIt *varEnd*)

Returns true if all specified variables are registered.

Parameters are iterators over a list of variable ids of type maxsum::VarID.

Parameters

varBegin	iterator to begining of variable list.
varEnd	iterator to end of variable list.

Returns

true if all registered, false otherwise.

6.1.3.2 template<class VarIt , class IndIt > void maxsum::condition (const DiscreteFunction & *inFun*, DiscreteFunction & *outFun*, VarIt *vBegin*, VarIt *vEnd*, IndIt *iBegin*, IndIt *iEnd*)

Condition function on specified variable values.

Changes a function so that it does not depend on any of the variables in the list specified by varBegin and varEnd, by conditioning these variables on a corresponding list of values.

Parameters

`in`	*inFun*	the function to condition
`out`	*outFun*	function in which to store result.
`in`	*vBegin*	iterator to start of variable list.
`in`	*vEnd*	iterator to end of variable list.
`in`	*iBegin*	iterator to start of value list.
`in`	*iEnd*	iterator to end of value list.

Precondition

parameters must be iterators over *sorted* lists.

Postcondition

Previous value of condition will be overwritten, and replaced with the conditioned values from inFun.

6.1.3.3 template<class VarMap > void maxsum::condition (const DiscreteFunction & *inFun*, DiscreteFunction & *outFun*, VarMap *vars*)

Condition function on specified variable values.

Changes a function so that it does not depend on any of the variables in the key set of the vars argument, by conditioning these variables on the values specified in vars.

Parameters

`in`	*inFun*	the function to condition
`out`	*outFun*	function in which to store result.
`in`	*vars*	maps conditioned vars to their assigned values.

Postcondition

Previous value of condition will be overwritten, and replaced with the conditioned values from inFun.

6.1.3.4 bool maxsum::equalWithinTolerance (const DiscreteFunction & *f1*, const DiscreteFunction & *f2*, ValType *tol* = `DEFAULT_VALUE_TOLERANCE`)

Check that two maxsum::DiscreteFunction objects are equal within a specified tolerance.

This function returns true if and only if, for all `k`:

```
-tol < 1-f1(k)/f2(k) < tol
```

Parameters

in	*f1*	First function to compare
in	*f2*	Second function to compare
in	*tol*	tolerance used for comparing values

See Also

maxsum::DEFAULT_VALUE_TOLERANCE

6.1.3.5 maxsum::ValIndex maxsum::getDomainSize (VarID *var*)

Returns the registered domain size for a specified variable.

Returns the domain size for a specified variable.

Parameters

var	id of the variable to search for.

Returns

domain size of var

Exceptions

UnknownVariableException	if the variable is not registered.

Parameters

var	id of the variable to search for.

Returns

domain size of var

Exceptions

UnknownVariableException	if variable is not registered.

6.1.3.6 int maxsum::getNumOfRegisteredVariables ( )

Returns the number of currently registered variables.

Returns

the number of currently registered variables.

6.1.3.7 template<class VecType > void maxsum::ind2sub (const VecType & *siz,* const typename VecType::value_type *ind,* VecType & *sub*)

C++ Implementation of Matlab ind2sub function.

Main difference here is that indices start from 0. In the special case where siz is empty, ind will also be empty.

Parameters

`in`	*siz*	of N-D array
`in`	*ind*	linear index
`out`	*sub*	vector in which we will put the sub indices.

Postcondition

previous contents of sub will be overwritten.

6.1.3.8 bool maxsum::isRegistered (VarID *var*)

Returns true if the specified variable is registered.

Parameters

var	id of the variable to search for.

Returns

true if the specified variable is registered.
true if the specified variable is registered.

6.1.3.9 template<typename F > void maxsum::marginal (const DiscreteFunction & *inFun,* F *aggregate,* DiscreteFunction & *outFun*)

Marginalise a maxsum::DiscreteFunction using a specified aggregation function.

This function reduces the domain of `inFun` to that of `outFun` and stores the result in `outFun`. This is done by aggregating over all variables that are in the domain of `inFun`, but not in the domain of `outFun`.

Aggregation is performed by a functor or function pointer, `aggregate`, which is passed as a template parameter. `aggregate` should be defined such that, in the code below, `z` is the aggregation of the function values `x` and `y`.

```
ValType x = inFun(k);
ValType y = inFun(t);
ValType z = aggregate(x,y); // result = aggregate(prevResult,nextVal)
```

Note that aggregate may be a function pointer, or any other object for which the above syntax is valid, such as a class instance that overloads the () operator, which may depend some internal state. The first argument to aggregate should always be the previous estimate, while the second is always the next value to be aggregated.

Various specialisations of this function are provided by maxsum::maxMarginal(), maxsum::minMarginal(), maxsum::meanMarginal().

In the special case where the domain of outFun is equal to the domain of inFun, outFun becomes a copy of inFun

Precondition

aggregate is a functor with signature `ValType aggregate(ValType prevResult, ValType nextVal)`
variables in domain of outFun are a subset of variables in inFun.

Postcondition

previous content of outFun is overwritten.
The domains of outFun and inFun remain unchanged.

Template Parameters

F	type of parameter aggregate.

Parameters

`in`	*inFun*	function to marginalise
`in`	*aggregate*	functor or function pointer used to aggregate results.
`out`	*outFun*	maxsum::DiscreteFunction in which to store result.

Exceptions

maxsum::BadDomain-Exception	is the domain of outFun is not a subset of inFun.

See Also

maxsum::maxMarginal()
maxsum::minMarginal()
maxsum::meanMarginal()

6.1.3.10 void maxsum::maxMarginal (const DiscreteFunction & *inFun*, DiscreteFunction & *outFun*)

Marginalise a maxsum::DiscreteFunction by maximisation.

This function reduces the domain of inFun to that of outFun by maximisation, and stores the result in outFun. This behaviour is equivalent to maxsum::marginal(inFun,std::max<ValType>,outFun).

Precondition

variables in domain of outFun are a subset of variables in inFun.

Postcondition

previous content of outFun is overwritten.
The domains of outFun and inFun remain unchanged.

Parameters

`in`	*inFun*	function to marginalise
`out`	*outFun*	maxsum::DiscreteFunction in which to store result.

Exceptions

maxsum::BadDomain-Exception	is the domain of outFun is not a subset of inFun.

See Also

maxsum::marginal()
maxsum::minMarginal()
maxsum::meanMarginal()

6.1.3.11 void maxsum::meanMarginal (const DiscreteFunction & *inFun*, DiscreteFunction & *outFun*)

Marginalise a maxsum::DiscreteFunction by averaging.

This function reduces the domain of inFun to that of outFun by averaging, and stores the result in outFun.

Precondition

variables in domain of outFun are a subset of variables in inFun.

Postcondition

previous content of outFun is overwritten.
The domains of outFun and inFun remain unchanged.

Parameters

`in`	*inFun*	function to marginalise
`out`	*outFun*	maxsum::DiscreteFunction in which to store result.

Exceptions

maxsum::BadDomainException	is the domain of outFun is not a subset of inFun.

See Also

maxsum::marginal()
maxsum::minMarginal()
maxsum::maxMarginal()

6.1.3.12 void maxsum::minMarginal (const DiscreteFunction & *inFun*, DiscreteFunction & *outFun*)

Marginalise a maxsum::DiscreteFunction by minimisation.

Marginal a maxsum::DiscreteFunction by minimisation.

This function reduces the domain of inFun to that of outFun by minimisation, and stores the result in outFun. This behaviour is equivalent to maxsum::marginal(inFun,std::min<ValType>,outFun).

Precondition

variables in domain of outFun are a subset of variables in inFun.

Postcondition

previous content of outFun is overwritten.
The domains of outFun and inFun remain unchanged.

Parameters

`in`	*inFun*	function to marginalise
`out`	*outFun*	maxsum::DiscreteFunction in which to store result.

Exceptions

maxsum::BadDomain-Exception	is the domain of outFun is not a subset of inFun.

See Also

maxsum::marginal()
maxsum::maxMarginal()
maxsum::meanMarginal()

This function reduces the domain of inFun to that of outFun by minimisation, and stores the result in outFun. This behaviour is equivalent to maxsum::marginal(inFun,std::min<ValType>,outFun).

Precondition

variables in domain of outFun are a subset of variables in inFun.

Postcondition

previous content of outFun is overwritten.
The domains of outFun and inFun remain unchanged.

Parameters

`in`	*inFun*	function to marginalise

Exceptions

maxsum::BadDomain-Exception	is the domain of outFun is not a subset of inFun.

Parameters

`out`	*outFun*	maxsum::DiscreteFunction in which to store result.

See Also

maxsum::marginal()
maxsum::maxMarginal()
maxsum::meanMarginal()

6.1.3.13 bool maxsum::operator!= (const DiscreteFunction & *f1*, const DiscreteFunction & *f2*) `[inline]`

Return true if functions are equal.

Two functions are equal if they have the same value over the cartesian product of their domains.

6.1.3.14 std::ostream & maxsum::operator<< (std::ostream & *out*, const DiscreteFunction & *fun*)

Pretty prints a maxsum::DiscreteFunction Format is similar to the disp function in Matlab for N-D arrays, except that first dimension appears in rows rather than columns.

Pretty prints a maxsum::DiscreteFunction.

Pretty prints this function.

Format is similar to the disp function in Matlab for N-D arrays, except that first dimension appears in rows rather than columns.

6.1.3.15 bool maxsum::operator== (const DiscreteFunction & *f1*, const DiscreteFunction & *f2*) [inline]

Return true if functions are equal.

Two functions are equal if they have the same value over the cartesian product of their domains.

6.1.3.16 void maxsum::registerVariable (VarID *var*, ValIndex *siz*)

Registers a variable with a specified domain size.

Puts the specified variable in a global register, and stores its domain size. Variables can be registered multiple times, but their domain size must never change.

Exceptions

InconsistentDomain-Exception	if this variable is already registered, but with a different domain size.

Parameters

var	the unique id of this variable
siz	the domain size of this variable

See Also

maxsum::registerVariables

Put the specified variable in a global register, and stores its domain size. Variables can be registered multiple times, but their domain size must never change.

Exceptions

InconsistentDomain-Exception	if this variable is already registered, but with a different domain size.

Parameters

var	the unique id of this variable
siz	the domain size of this variable

6.1.3.17 template<class VarIt , class IndIt > void maxsum::registerVariables (VarIt *varBegin*, VarIt *varEnd*, IndIt *sizBegin*, IndIt *sizEnd*)

Register a list of variables with specified domain sizes.

This works in the same was as maxsum::registerVariable - but does so for multiple variables at a time. The parameters varBegin and varEnd are iterators to the beginning and end of a list of variable ids, while sizBegin and sizEnd specify the start and end of a list of their respective domain sizes. Both lists must be ordered such that the kth element of the size list is the domain size for the kth variable in the variable list.

Parameters

varBegin	iterator to the start of a list of maxsum::VarID
varEnd	iterator to the end of a list of maxsum::VarID

sizBegin	iterator to the start of a list of maxsum::ValIndex
sizEnd	iterator to the start of a list of maxsum::ValIndex

See Also

maxsum::registerVariable

6.1.3.18 bool maxsum::sameDomain (const DiscreteFunction & *f1*, const DiscreteFunction & *f2*)

Check that two maxsum::DiscreteFunction objects have the same domain.

Two functions have the same domain, if they depend on the same set of variables.

Parameters

in	*f1*	First function to compare
in	*f2*	Second functions to compare

Returns

true if both function have the same domain.

6.1.3.19 bool maxsum::strictlyEqualWithinTolerance (const DiscreteFunction & *f1*, const DiscreteFunction & *f2*, ValType *tol* = `DEFAULT_VALUE_TOLERANCE`)

Check that two maxsum::DiscreteFunction objects are equal with a specified tolerance, and have exactly the same domain.

This function returns true if and only if:

```
true == sameDomain(f1,f2) && equalWithinTolerance(f1,f2,tol)
```

Parameters

in	*f1*	First function to compare
in	*f2*	Second function to compare
in	*tol*	tolerance used for comparing values

See Also

maxsum::DEFAULT_VALUE_TOLERANCE

6.1.3.20 template<class SizIt , class SubIt > ValIndex maxsum::sub2ind (SizIt *sizFirst*, SizIt *sizEnd*, SubIt *subFirst*, SubIt *subEnd*)

C++ Implementation of Matlab sub2ind function.

Main difference here is that indices start from 0.

Parameters

in	*sizFirst*	iterator to first element of size array.
in	*sizEnd*	iterator to end element of size array.
in	*subFirst*	iterator to first element of subindex array.
in	*subEnd*	iterator to first element of subindex array.

Returns

linear index

6.1.3.21 template< class VecType > VecType::value_type maxsum::sub2ind (const VecType & *siz*, const VecType & *sub*)

C++ Implementation of Matlab sub2ind function.

Main difference here is that indices start from 0.

Parameters

in	*siz*	of N-D array
in	*sub*	empty vector in which we will put the sub indices.

Returns

linear index

6.1.4 Variable Documentation

6.1.4.1 const ValType maxsum::DEFAULT_VALUE_TOLERANCE = DBL_EPSILON * 1000.0

Default tolerance used for comparing values of type maxsum::ValType.

This is the default value used by the maxsum::equalWithinTolerance function, when comparing to maxsum::-DiscreteFunction objects for equality. Note, if ValType is ever redefined, then this value should be changed appropriately also.

See Also

maxsum::equalWithinTolerance

6.2 maxsum::util Namespace Reference

Utility namespace for types used for maxsum library implementation.

Classes

- class PostOffice

  Class used to store and manage messages sent between factor graph nodes.
- class KeySet

  Utility class for presenting the keys of a map in a read-only container.
- class RefMap

  This class provides a read only wrapper around an existing map, such as that provided by std::map.

Typedefs

- typedef PostOffice< VarID,
  FactorID > V2FPostOffice

  Convenience typedef for Variable to Factor PostOffices.
- typedef PostOffice< FactorID,
  VarID > F2VPostOffice

  Convenience typedef for Factor to Variable PostOffices.

- typedef PostOffice< FactorID,
  FactorID > F2FPostOffice

  Convenience typedef for Factor to Factor PostOffices.

6.2.1 Detailed Description

Utility namespace for types used for maxsum library implementation. The contents of this namespace are not intended to form part of the external interface to the maxsum library, and can be safely ignored by third party developers.

Chapter 7

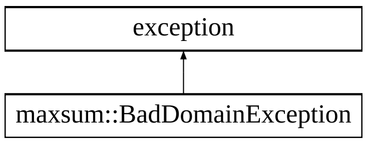
Class Documentation

7.1 maxsum::BadDomainException Class Reference

Exception thrown when subindices are incorrectly specified for a maxsum::DiscreteFunction.

```
#include <exceptions.h>
```

Inheritance diagram for maxsum::BadDomainException:



Public Member Functions

- BadDomainException (const std::string where_, const std::string mesg_) throw ()

    Constructs a new exception with specified location and message.

- const char $*$ what () const throw ()

    Returns a message describing the cause of this exception, and the location it was thrown.

- virtual $\sim$BadDomainException () throw ()

    Destroys this exception and free's its allocated resources.

Protected Attributes

- const std::string where

    String identifying the source code locatioin where this exceptioin was generated.

- const std::string mesg

    Message describing the cause of this exception.

7.1.1 Detailed Description

Exception thrown when subindices are incorrectly specified for a maxsum::DiscreteFunction.

7.1.2 Constructor & Destructor Documentation

7.1.2.1 maxsum::BadDomainException::BadDomainException (const std::string *where_*, const std::string *mesg_*) throw () [inline]

Constructs a new exception with specified location and message.

Parameters

in	*where_*	the source code location where this exception was generated.
in	*mesg_*	Message describing the reason for this exception.

7.1.3 Member Function Documentation

7.1.3.1 const char∗ maxsum::BadDomainException::what ( ) const throw () [inline]

Returns a message describing the cause of this exception, and the location it was thrown.

Returns

a message describing the cause of this exception, and the location it was thrown.

The documentation for this class was generated from the following file:

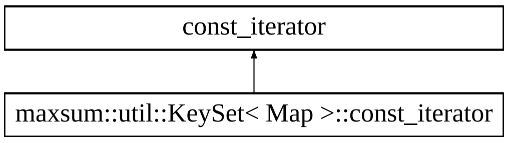
- include/exceptions.h

7.2 maxsum::util::KeySet< Map >::const_iterator Class Reference

Iterator type that allows read-only access to the keys of the underlying map.

```
#include <util_containers.h>
```

Inheritance diagram for maxsum::util::KeySet< Map >::const_iterator:



Public Member Functions

- const_iterator (typename Map::const_iterator it)

  Constructs a new KeySet iterator from a map iterator.
- const KeySet::value_type & operator∗ () const

  Overrides dereference operator so that a direct reference to the Map key is returned.

7.2.1 Detailed Description

template<class Map>class maxsum::util::KeySet< Map >::const_iterator

Iterator type that allows read-only access to the keys of the underlying map.

This is achieved by overriding the map iterator's own dereferencing operator, so that only a constant reference to the key is returned.

The documentation for this class was generated from the following file:

- include/util_containers.h

7.3 maxsum::DiscreteFunction Class Reference

Class representing functions of sets of variables with discrete domains.

`#include <DiscreteFunction.h>`

Public Types

- typedef std::vector< VarID >
  ::const_iterator VarIterator

  Type of iterator returned by DiscreteFunction::varBegin() and DiscreteFunction::varEnd() functions.
- typedef std::vector< ValIndex >
  ::const_iterator SizeIterator

  Type of iterator returned by DiscreteFunction::sizeBegin() and DiscreteFunction::sizeEnd() functions.

Public Member Functions

- DiscreteFunction (ValType val=0)

  Default Constructor creates constant function that depends on no variables.
- template<class VarIt >
  DiscreteFunction (VarIt begin, VarIt end, ValType val=0)

  Constructs function depending on specified variables.
- DiscreteFunction (VarID var, ValType val)

  Constructs a function that depends on only one variable.
- DiscreteFunction (const DiscreteFunction &val)

  Copy Constructor performs deep copy.
- ValIndex domainSize () const

  Accessor method for the total size this function's domain.
- bool dependsOn (VarID var) const

  Returns true if this function depends on the specified variable.
- VarIterator varBegin () const

  Returns an iterator to the start of this function's domain variable list.
- VarIterator varEnd () const

  Returns an iterator to the end of this function's domain variable list.
- SizeIterator sizeBegin () const

  Returns an iterator to the start of this function's domain variable size list.
- SizeIterator sizeEnd () const

  Returns an iterator to the end of this function's domain variable size list.
- int noVars () const

  Returns the number of variables on which this function depends.
- DiscreteFunction & operator= (ValType val)

  Sets this function to a constant scalar value.
- DiscreteFunction & operator= (const DiscreteFunction &val)

  Sets this function to be equal to another.
- DiscreteFunction & operator+= (ValType val)

  Adds a scalar value to this function.
- DiscreteFunction & operator-= (ValType val)

Subtracts a scalar value from this function.

- DiscreteFunction & operator∗= (ValType val)

  Multiplies this function by a scalar.
- DiscreteFunction & operator/= (ValType val)

  Divides this function by a scalar.
- DiscreteFunction operator- ()

  Multiply function by -1.
- DiscreteFunction & operator+ ()

  Identity function.
- DiscreteFunction & operator+= (const DiscreteFunction &rhs)

  Adds a function to this one, expanding the domain if necessary.
- DiscreteFunction & operator-= (const DiscreteFunction &rhs)

  Subtracts a function from this one, expanding domain if necessary.
- DiscreteFunction & operator∗= (const DiscreteFunction &rhs)

  Multiplies this function by another, expanding domain if necessary.
- DiscreteFunction & operator/= (const DiscreteFunction &rhs)

  Divides this function by another, expanding domain if necessary.
- template<class T >
  DiscreteFunction operator- (T rhs) const

  Subtract function or scalar.
- template<class T >
  DiscreteFunction operator+ (T rhs) const

  Add function or scalar.
- template<class T >
  DiscreteFunction operator∗ (T rhs) const

  Multiply function or scalar.
- template<class T >
  DiscreteFunction operator/ (T rhs) const

  Divide function by function or scalar.
- template<class VecIt >
  DiscreteFunction & add (VecIt begin, VecIt end)

  Adds a list of Functions to this one, expanding the domain if necessary.
- ValType & operator() (ValIndex ind)

  Access coefficient using linear index.
- const ValType & operator() (ValIndex ind) const

  Access coefficient using linear index.
- ValType & operator() (ValIndex ind1, ValIndex ind2,...)

  Access coefficient using subindices specified in argument list.
- const ValType & operator() (ValIndex ind1, ValIndex ind2,...) const

  Access coefficient using subindices specified in argument list.
- ValType & at (ValIndex ind)

  Access coefficient using scalar index.
- const ValType & at (ValIndex ind) const

  Access coefficient using scalar index.
- ValType & at (ValIndex ind1, ValIndex ind2,...)

  Access coefficient using subindices specified as argumments This is equivalent to DiscreteFunction::operator() but is more convenient when for use with pointers e.g.
- const ValType & at (ValIndex ind1, ValIndex ind2,...) const

  Access coefficient using subindices specified as argumments This is equivalent to DiscreteFunction::operator() but is more convenient when for use with pointers e.g.
- template<class IndIt >
  ValType & operator() (IndIt begin, IndIt end)

Access coefficient by subindices.

- template<class IndIt >
  const ValType & operator() (IndIt begin, IndIt end) const

  Access coefficient by subindices.
- template<class VarIt , class IndIt >
  ValType & operator() (VarIt varBegin, VarIt varEnd, IndIt indBegin, IndIt indEnd)

  Access coefficient by subindices for specified variables.
- template<class VarIt , class IndIt >
  const ValType & operator() (VarIt varBegin, VarIt varEnd, IndIt indBegin, IndIt indEnd) const

  Access coefficient by subindices for specified variables.
- template<class VarVec , class IndVec >
  ValType & operator() (VarVec var, IndVec ind)

  Access coefficient by subindices for specified variables.
- template<class VarVec , class IndVec >
  const ValType & operator() (VarVec var, IndVec ind) const

  Access coefficient by subindices for specified variables.
- template<class VarMap >
  ValType & operator() (const VarMap &vals)

  Access coefficient by subindices specified in variable map.
- template<class VarMap >
  const ValType & operator() (const VarMap &vals) const

  Access coefficient by subindices specified in variable map.
- ValType & operator() (const DomainIterator &it)

  Access coefficient by subindices specified by the current indices specified by a maxsum::DomainIterator.
- const ValType & operator() (const DomainIterator &it) const

  Access coefficient by subindices specified by the current indices specified by a maxsum::DomainIterator.
- void swap (DiscreteFunction &fun)

  Swaps the value and domain of this function with another.
- template<class VarInd >
  void expand (VarInd begin, VarInd end)

  Make this function depend on additional variables.
- void expand (const VarID var)

  Expand the domain of this function to include a named variable.
- void expand (const DiscreteFunction &fun)

  Make the domain of this function include the domain of another.
- template<class VarIt , class IndIt >
  void condition (VarIt vBegin, VarIt vEnd, IndIt iBegin, IndIt iEnd)

  Condition function on specified variable values.
- ValType min () const

  Returns the minimum scalar value of the function across entire domain.
- ValType max () const

  Returns the maximum scalar value for function across entire domain.
- ValIndex argmax () const

  Returns the linear index of the maximum value accross entire domain.
- ValType maxnorm () const

  Returns the maxnorm for this function.
- ValType mean () const

  Returns the mean scalar value for function across entire domain.

Friends

- std::ostream & operator<< (std::ostream &out, const DiscreteFunction &fun)

  Pretty prints this function.

7.3.1 Detailed Description

Class representing functions of sets of variables with discrete domains.

Template Parameters

ValType	the scalar type of value returned by this function. We expect this to by a primitive numeric type, such as double or int.

7.3.2 Constructor & Destructor Documentation

7.3.2.1 maxsum::DiscreteFunction::DiscreteFunction (**ValType** *val* = `0`) `[inline]`

Default Constructor creates constant function that depends on no variables.

Parameters

`in`	*val*	the constant scalar value of this function.

7.3.2.2 template<class VarIt > maxsum::DiscreteFunction::DiscreteFunction (VarIt *begin*, VarIt *end*, **ValType** *val* = `0`) `[inline]`

Constructs function depending on specified variables.

When passing variable ids, we assume that the list is unique and sorted. Initially, for any input the function returns the value of the val parameter, which defaults to zero.

Parameters

`in`	*begin*	Iterator to start of variable list.
`in`	*end*	Iterator to end of variable list.
`in`	*val*	inital scalar value output for function.

Exceptions

UnknownVariableException	if any variable in the list specified by `begin` and `end` is not registered.

7.3.2.3 maxsum::DiscreteFunction::DiscreteFunction (**VarID** *var*, **ValType** *val*) `[inline]`

Constructs a function that depends on only one variable.

Parameters

`in`	*var*	the variable to put in this function's domain.
`in`	*val*	scalar value used to initialise function across domain.

Postcondition

$\forall k \; f(k) = val$

Exceptions

UnknownVariableException	if `var` is not registered.

7.3.2.4 maxsum::DiscreteFunction::DiscreteFunction (const DiscreteFunction & *val*) [inline]

Copy Constructor performs deep copy.

Parameters

in	*val*	the object to copy.

7.3.3 Member Function Documentation

7.3.3.1 template<class VecIt > DiscreteFunction& maxsum::DiscreteFunction::add (VecIt *begin,* VecIt *end*) [inline]

Adds a list of Functions to this one, expanding the domain if necessary.

The result is $this + \sum_k funcs[k]$

Returns

reference to this function.

7.3.3.2 ValType& maxsum::DiscreteFunction::at (ValIndex *ind*) [inline]

Access coefficient using scalar index.

This is equivalent to DiscreteFunction::operator()(maxsum::ValIndex ind) but is more convenient when for use with pointers e.g.

```
x->(k); // illegal
x->at(k); // ok
```

See Also

DiscreteFunction::operator()(maxsum::ValIndex ind)

7.3.3.3 const ValType& maxsum::DiscreteFunction::at (ValIndex *ind*) const [inline]

Access coefficient using scalar index.

This is equivalent to DiscreteFunction::operator()(maxsum::ValIndex ind) const but is more convenient when for use with pointers e.g.

```
x->(k); // illegal
x->at(k); // ok
```

See Also

DiscreteFunction::operator()(maxsum::ValIndex ind) const

7.3.3.4 ValType & DiscreteFunction::at (ValIndex *ind1,* ValIndex *ind2,* ...)

Access coefficient using subindices specified as argumments This is equivalent to DiscreteFunction::operator() but is more convenient when for use with pointers e.g.

```
x->(k); // illegal
x->at(k); // ok
```

See Also

DiscreteFunction::operator()

```
x->(k); // illegal
x->at(k); // ok
```

See Also

DiscreteFunction::operator()

7.3.3.5 const ValType & DiscreteFunction::at (ValIndex *ind1,* ValIndex *ind2,* ...) const

Access coefficient using subindices specified as argumments This is equivalent to DiscreteFunction::operator() but is more convenient when for use with pointers e.g.

```
x->(k); // illegal
x->at(k); // ok
```

See Also

DiscreteFunction::operator()

```
x->(k); // illegal
x->at(k); // ok
```

See Also

DiscreteFunction::operator()

7.3.3.6 template<class VarIt , class IndIt > void maxsum::DiscreteFunction::condition (VarIt *vBegin,* VarIt *vEnd,* IndIt *iBegin,* IndIt *iEnd*) [inline]

Condition function on specified variable values.

Changes this function so that it does not depend on any of the variables in the list specified by varBegin and varEnd, by conditioning this variables on a corresponding list of values.

Parameters

in	*vBegin*	iterator to start of variable list.
in	*vEnd*	iterator to end of variable list.
in	*iBegin*	iterator to start of value list.
in	*iEnd*	iterator to end of value list.

Precondition

parameters must be iterators over *sorted* lists.

Postcondition

After calling this method, this DiscreteFunction will not depend on any of the variables in the list specified by varBegin and varEnd.

7.3.3.7 bool DiscreteFunction::dependsOn (VarID *var*) const

Returns true if this function depends on the specified variable.

Parameters

`in`	*var*	The id of the variable to search for in this function's domain.

Returns

true if `var` is in this function's domain.

7.3.3.8 template<class VarInd > void maxsum::DiscreteFunction::expand (VarInd *begin*, VarInd *end*) [inline]

Make this function depend on additional variables.

If necessary, the domain of this function is expanded to include the specified list of variables.

Parameters

`in`	*begin*	iterator to first variable to add
`in`	*end*	iterator to end of list of variables.

7.3.3.9 void DiscreteFunction::expand (const VarID *var*)

Expand the domain of this function to include a named variable.

Parameters

`in`	*var*	the id of the variable to add to this function's domain.

Postcondition

The domain of this function is the union of its previous domain, and the additional specified variable.

7.3.3.10 void DiscreteFunction::expand (const DiscreteFunction & *fun*)

Make the domain of this function include the domain of another.

If necessary, the domain of this function is expanded to include the domain of the parameter fun.

Parameters

`in`	*fun*	function whose domain we want to expand to.

Postcondition

domain of this is union of its previous domain, with that of fun.

If necessary, the domain of this function is expanded to include the domain of the parameter fun.

Parameters

`in`	*fun*	function whose domain we want to expand to.

Postcondition

domain of this is union of its previous domain, with that of fun.

7.3.3.11 ValType DiscreteFunction::maxnorm ( ) const

Returns the maxnorm for this function.

The maxnorm is defined as the maximum absolute value of the function:

$$\|f(k)\|_\infty = \max_k |f(k)|$$

7.3.3.12 ValType DiscreteFunction::min ( ) const

Returns the minimum scalar value of the function across entire domain.

Returns the maximum scalar value for function across entire domain.

7.3.3.13 ValType & DiscreteFunction::operator() (ValIndex *ind1*, ValIndex *ind2*, ...)

Access coefficient using subindices specified in argument list.

Number of arguments needs to match the number of variables in this function's domain, otherwise bad things will happen.

7.3.3.14 template<class VarIt , class IndIt > ValType& maxsum::DiscreteFunction::operator() (VarIt *varBegin*, VarIt *varEnd*, IndIt *indBegin*, IndIt *indEnd*) `[inline]`

Access coefficient by subindices for specified variables.

Specified variables must be superset of variables on which this function depends.

7.3.3.15 template<class VarIt , class IndIt > const ValType& maxsum::DiscreteFunction::operator() (VarIt *varBegin*, VarIt *varEnd*, IndIt *indBegin*, IndIt *indEnd*) const `[inline]`

Access coefficient by subindices for specified variables.

Specified variables must be superset of variables on which this function depends.

7.3.3.16 template<class VarVec , class IndVec > ValType& maxsum::DiscreteFunction::operator() (VarVec *var*, IndVec *ind*) `[inline]`

Access coefficient by subindices for specified variables.

Specified variables must be superset of variables on which this function depends.

7.3.3.17 template<class VarVec , class IndVec > const ValType& maxsum::DiscreteFunction::operator() (VarVec *var*, IndVec *ind*) const `[inline]`

Access coefficient by subindices for specified variables.

Specified variables must be superset of variables on which this function depends.

7.3.3.18 template<class VarMap > ValType& maxsum::DiscreteFunction::operator() (const VarMap & *vals*) [inline]

Access coefficient by subindices specified in variable map.

Specified variables must be superset of variables on which this function depends. The specified map must be sorted.

Parameters

vals	map of VarID (variables) to ValIndex (values)

Precondition

iterators over vals must return pairs in ascending key order.

7.3.3.19 template<class VarMap > const ValType& maxsum::DiscreteFunction::operator() (const VarMap & *vals*) const [inline]

Access coefficient by subindices specified in variable map.

Specified variables must be superset of variables on which this function depends. The specified map must be sorted.

Parameters

vals	map of VarID (variables) to ValIndex (values)

Precondition

iterators over vals must return pairs in ascending key order.

7.3.3.20 ValType & DiscreteFunction::operator() (const DomainIterator & *it*)

Access coefficient by subindices specified by the current indices specified by a maxsum::DomainIterator.

Note: this works by accessing maxsum::DomainIterator::getSubInd() array. If the domain of the maxsum::Domain-Iterator exactly matches the domain of this function, then it is more efficient to index using the corresponding linear index instead. That is

```
maxsum::DiscreteFunction f(...); // some function
maxsum::DomainIterator it(f); // iterator over domain of f
maxsum::ValType x = f(it); // this works
maxsum::ValType x = f(it.getInd()); // more efficient in this case.
```

Parameters

in	*it*	Iterator used to index this function.

See Also

maxsum::DomainIterator::getSubInd()
maxsum::DomainIterator::getInd()

Note: this works by accessing maxsum::DomainIterator::getSubInd() array. If the domain of the maxsum::Domain-Iterator exactly matches the domain of this function, then it is more efficient to index using the corresponding linear index instead. That is

```
maxsum::DiscreteFunction f(...); // some function maxsum::DomainIterator
```

```
it(f); // iterator over domain of f maxsum::ValType x = f(it); // this works
maxsum::ValType x = f(it.getInd()); // more efficient in this case.
```

Parameters

in	*it*	Iterator used to index this function.

See Also

maxsum::DomainIterator::getSubInd()
maxsum::DomainIterator::getInd()

7.3.3.21 const ValType & DiscreteFunction::operator() (const DomainIterator & *it*) const

Access coefficient by subindices specified by the current indices specified by a maxsum::DomainIterator.

Note: this works by accessing maxsum::DomainIterator::getSubInd() array. If the domain of the maxsum::Domain-Iterator exactly matches the domain of this function, then it is more efficient to index using the corresponding linear index instead. That is

```
maxsum::DiscreteFunction f(...); // some function
maxsum::DomainIterator it(f); // iterator over domain of f
maxsum::ValType x = f(it); // this works
maxsum::ValType x = f(it.getInd()); // more efficient in this case.
```

Parameters

in	*it*	Iterator used to index this function.

See Also

maxsum::DomainIterator::getSubInd()
maxsum::DomainIterator::getInd()

Note: this works by accessing maxsum::DomainIterator::getSubInd() array. If the domain of the maxsum::Domain-Iterator exactly matches the domain of this function, then it is more efficient to index using the corresponding linear index instead. That is

```
maxsum::DiscreteFunction f(...); // some function maxsum::DomainIterator
it(f); // iterator over domain of f maxsum::ValType x = f(it); // this works
maxsum::ValType x = f(it.getInd()); // more efficient in this case.
```

Parameters

in	*it*	Iterator used to index this function.

See Also

maxsum::DomainIterator::getSubInd()
maxsum::DomainIterator::getInd()

7.3.3.22 DiscreteFunction& maxsum::DiscreteFunction::operator+ ( ) [inline]

Identity function.

Returns

a reference to this function.

7.3.3.23 DiscreteFunction & DiscreteFunction::operator= (ValType *val*)

Sets this function to a constant scalar value.

Parameters

in	*val*	the value to assign to this function.

7.3.3.24 DiscreteFunction & DiscreteFunction::operator= (const DiscreteFunction & *val*)

Sets this function to be equal to another.

Parameters

in	*val*	the value to assign to this function.

7.3.3.25 SizeIterator maxsum::DiscreteFunction::sizeBegin ( ) const [inline]

Returns an iterator to the start of this function's domain variable size list.

This list cannot be modified through this iterator. The values in this list are defined such that size[k] = maxsum::get-DomainSize(var[k]); However, this method is generally faster than using maxsum::getDomainSize() directly.

See Also

maxsum::getDomainSize()
DiscreteFunction::sizeEnd()

7.3.3.26 SizeIterator maxsum::DiscreteFunction::sizeEnd ( ) const [inline]

Returns an iterator to the end of this function's domain variable size list.

This list cannot be modified through this iterator. The values in this list are defined such that size[k] = maxsum::get-DomainSize(var[k]); However, this method is generally faster than using maxsum::getDomainSize() directly.

See Also

maxsum::getDomainSize()
DiscreteFunction::sizeBegin()

7.3.3.27 void DiscreteFunction::swap (DiscreteFunction & *fun*)

Swaps the value and domain of this function with another.

After the call to this member function, the elements in this function are those which were in fun before the call, and the elements of fun are those which were in this.

Parameters

fun	Another DiscreteFunction whose value and domain is swapped with that of this one.

7.3.3.28 VarIterator maxsum::DiscreteFunction::varBegin ( ) const [inline]

Returns an iterator to the start of this function's domain variable list.

The variable list cannot be modified through this iterator.

7.3.3.29 VarIterator maxsum::DiscreteFunction::varEnd ( ) const [inline]

Returns an iterator to the end of this function's domain variable list.

This variable list cannot be modified through this iterator.

7.3.4 Friends And Related Function Documentation

7.3.4.1 std::ostream& operator<< (std::ostream & *out*, const DiscreteFunction & *fun*) [friend]

Pretty prints this function.

Format is similar to the disp function in Matlab for N-D arrays, except that first dimension appears in rows rather than columns.

The documentation for this class was generated from the following files:

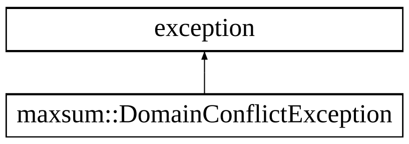
- include/DiscreteFunction.h
- src/DiscreteFunction.cpp

7.4 maxsum::DomainConflictException Class Reference

Exception thrown when conflicting domains are specified for a variable.

`#include <exceptions.h>`

Inheritance diagram for maxsum::DomainConflictException:



Public Member Functions

- DomainConflictException (const std::string where_, const std::string mesg_) throw ()

    Creates a new expection of this type.
- const char ∗ what () const throw ()

    Returns a message describing the cause of this exception, and the location it was thrown.
- virtual ∼DomainConflictException () throw ()

    Destroys this exception and free's its allocated resources.

Protected Attributes

- const std::string where

    String identifying the source code locatioin where this exceptioin was generated.
- const std::string mesg

    Message describing the cause of this exception.

7.4.1 Detailed Description

Exception thrown when conflicting domains are specified for a variable.

7.4.2 Constructor & Destructor Documentation

7.4.2.1 maxsum::DomainConflictException::DomainConflictException (const std::string *where_*, const std::string *mesg_*) throw () `[inline]`

Creates a new expection of this type.

Parameters

`in`	*where_*	the position in the source code where this was generated.
`in`	*mesg_*	message describing the cause of this exception.

7.4.3 Member Function Documentation

7.4.3.1 const char∗ maxsum::DomainConflictException::what ( ) const throw () `[inline]`

Returns a message describing the cause of this exception, and the location it was thrown.

Returns

a message describing the cause of this exception, and the location it was thrown.

The documentation for this class was generated from the following file:

- include/exceptions.h

7.5 maxsum::DomainIterator Class Reference

This class provides methods for iterating over the Cartesian product for a set of variable domains.

`#include <DomainIterator.h>`

Public Types

- typedef std::vector< VarID > VarList

  Type of list returned by DomainIterator::getVars()
- typedef std::vector< ValIndex > IndList

  Type of list returned by DomainIterator::getSubInd()

Public Member Functions

- void validateRange () const

  Utility method that throws an exception if we try to access beyond the end of the domain.
- DomainIterator ()

  Default Constructor.
- template<class It >
  DomainIterator (It begin, It end)

  Construct Domain iterator with initial list of variables.

- DomainIterator (const DiscreteFunction &fun)

    Construct Domain Iterator using domain of a given function.
- DomainIterator (const DomainIterator &it)

    Copy constructor.
- DomainIterator & operator= (const DomainIterator &it)

    Copy assignment.
- bool hasNext () const

    Returns true if next call to DomainIterator::operator++() will not throw an exception.
- const IndList & getSubInd () const

    Accessor method for current sub indices.
- ValIndex getInd () const

    Accessor method for linear index.
- const VarList & getVars () const

    Accessor method for variables in domain.
- bool isFixed (VarID var) const

    Returns true if this function is conditioned on the specified variable.
- int fixedCount () const

    Returns the number of conditioned variables for this function.
- template<class It >
  void addVars (It begin, It end)

    Add the specified variables to the domain of this iterator.
- DomainIterator & operator++ ()

    Increment this iterator to the next element in the domain.
- DomainIterator operator++ (int)

    Increment this iterator to the next element in the domain.
- template<class VarIt , class IndIt >
  void condition (const VarIt varBegin, const VarIt varEnd, const IndIt indBegin, const IndIt indEnd)

    Condition domain on specified variable values.
- template<class VarMap >
  void condition (const VarMap &vars)

    Condition domain on specified variable values.
- void condition (const DomainIterator &it)

    Convenience function for conditioning one iterator on the current value of another.

7.5.1 Detailed Description

This class provides methods for iterating over the Cartesian product for a set of variable domains.

7.5.2 Constructor & Destructor Documentation

7.5.2.1 maxsum::DomainIterator::DomainIterator ( ) [inline]

Default Constructor.

Creates Iterator over empty domain. Unless DomainIterator::addVars() is subsequently called DomainIterator::getVars() and DomainIterator::getSubInd() will return empty lists, and DomainIterator::operator++() will throw an exception.

7.5.2.2 template<class It > maxsum::DomainIterator::DomainIterator (It *begin*, It *end*) [inline]

Construct Domain iterator with initial list of variables.

Template Parameters

type	of list iterator used for arguments

Parameters

begin	iterator to first variable in list
end	iterator to end of variable list

7.5.2.3 DomainIterator::DomainIterator (const DiscreteFunction & *fun*)

Construct Domain Iterator using domain of a given function.

This is more efficient that creating from sratch.

Parameters

in	*fun*	Function whose domain should be copied.

7.5.3 Member Function Documentation

7.5.3.1 template<class It > void maxsum::DomainIterator::addVars (It *begin*, It *end*) [inline]

Add the specified variables to the domain of this iterator.

Template Parameters

It	iterator type for input variables.

Parameters

begin	iterator to start of variable list to add.
end	iterator to end of variable list to add.

Postcondition

DomainIterator::getVars() will return set union of old variable set and input variable set.
DomainIterator::hasNext() will return true.
Existing conditioned variables will remain conditioned and will have their values preserved. All other variables will have subindex 0.

7.5.3.2 template<class VarIt , class IndIt > void maxsum::DomainIterator::condition (const VarIt *varBegin*, const VarIt *varEnd*, const IndIt *indBegin*, const IndIt *indEnd*) [inline]

Condition domain on specified variable values.

Changes this iterator so that the specified set of variables have fixed values, and are not incremented. The parameters indBegin and indEnd specify the list of values that the corresponding variables should be set to instead. Any variables pointed to by varBegin and varEnd that are not it this iterators domain will be ignored.

Precondition

varBegin and varEnd are iterators to a *sorted* list of maxsum::VarID.
Values in list specified by indBegin and indEnd must be between 0, and their respective variable domain size.

Postcondition

All free indices are set back to 0, and DomainIterator::hasNext() returns true.
Previously conditioned variables have their values perserved.

Exceptions

OutOfRangeException	is specified condition values are out of range.

Parameters

in	*varBegin*	iterator to start of variable list.
in	*varEnd*	iterator to end of variable list.
in	*indBegin*	iterator to start of value list.
in	*indEnd*	iterator to end of value list.

7.5.3.3 template< class VarMap > void maxsum::DomainIterator::condition (const VarMap & *vars*) [inline]

Condition domain on specified variable values.

Changes this iterator so that the specified set of variables have fixed values, and are not incremented.

Precondition

Values in vars map must be between 0, and their respective variable domain size.

Postcondition

All free indices are set back to 0, and DomainIterator::hasNext() returns true.
Previously conditioned variables have their values perserved.

Exceptions

OutOfRangeException	is specified condition values are out of range.

Parameters

in	*varBegin*	iterator to start of variable list.
in	*varEnd*	iterator to end of variable list.
in	*indBegin*	iterator to start of value list.
in	*indEnd*	iterator to end of value list.

7.5.3.4 void DomainIterator::condition (const DomainIterator & *it*)

Convenience function for conditioning one iterator on the current value of another.

This equalivalent to the following code

```
DomainIterator it1(...), it2(...);
DomainIterator::VarList vars = it1.getVars();
```

```
DomainIterator::IndList inds = it1.getSubInd();
it2.condition(vars.begin(),vars.end(),inds.begin(), inds.end());
```

See Also

DomainIterator::condition(const VarIt,const VarIt,const IndIt,const IndIt)

7.5.3.5 ValIndex maxsum::DomainIterator::getInd ( ) const [inline]

Accessor method for linear index.

Exceptions

maxsum::OutOfRange-Exception	if iterator is out of range.

7.5.3.6 const IndList& maxsum::DomainIterator::getSubInd ( ) const [inline]

Accessor method for current sub indices.

Exceptions

maxsum::OutOfRange-Exception	if iterator is out of range.

7.5.3.7 bool maxsum::DomainIterator::hasNext ( ) const [inline]

Returns true if next call to DomainIterator::operator++() will not throw an exception.

This is true provided all free (unconditioned) variables are less than their corresponding maximum: maxsum::get-DomainSize(maxsum::VarID) - 1.

See Also

maxsum::getDomainSize(maxsum::VarID)
DomainIterator::condition()

7.5.3.8 DomainIterator & DomainIterator::operator++ ( )

Increment this iterator to the next element in the domain.

This is the prefix version: increment first, then return.

Exceptions

OutOfRangeException	if we are already at the last element.

Returns

iterator to next element

This is the prefix version: increment first, then return.

Exceptions

maxsum::OutOfRange-Exception	if we are already at the last element.

Returns

iterator to next element

7.5.3.9 DomainIterator maxsum::DomainIterator::operator++ (int) [inline]

Increment this iterator to the next element in the domain.

This is the postfix version: return current value, then increment.

Exceptions

OutOfRangeException	if we are already at the last element.

Returns

iterator to next element

7.5.3.10 void maxsum::DomainIterator::validateRange ( ) const [inline]

Utility method that throws an exception if we try to access beyond the end of the domain.

Exceptions

maxsum::OutOfRange-Exception	if we've reached the end of the list.

The documentation for this class was generated from the following files:

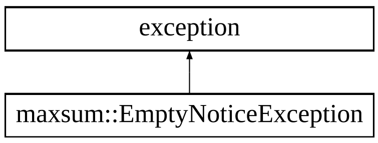
- include/DomainIterator.h
- src/DomainIterator.cpp

7.6 maxsum::EmptyNoticeException Class Reference

Exception thrown by maxsum::util::PostOffice::popNotice when there are no active notices.

`#include <exceptions.h>`

Inheritance diagram for maxsum::EmptyNoticeException:



Public Member Functions

- EmptyNoticeException (const std::string where_, const std::string mesg_) throw ()

Constructs a new exception with specified location and message.

- const char ∗ what () const throw ()

  Returns a message describing the cause of this exception, and the location it was thrown.
- virtual ∼EmptyNoticeException () throw ()

  Destroys this exception and free's its allocated resources.

Protected Attributes

- const std::string where

  String identifying the source code locatioin where this exceptioin was generated.
- const std::string mesg

  Message describing the cause of this exception.

7.6.1 Detailed Description

Exception thrown by maxsum::util::PostOffice::popNotice when there are no active notices.

See Also

PostOffice::popNotice

7.6.2 Constructor & Destructor Documentation

7.6.2.1 maxsum::EmptyNoticeException::EmptyNoticeException (const std::string *where_*, const std::string *mesg_*) throw () [inline]

Constructs a new exception with specified location and message.

Parameters

in	*where_*	the source code location where this exception was generated.
in	*mesg_*	Message describing the reason for this exception.

7.6.3 Member Function Documentation

7.6.3.1 const char∗ maxsum::EmptyNoticeException::what ( ) const throw () [inline]

Returns a message describing the cause of this exception, and the location it was thrown.

Returns

a message describing the cause of this exception, and the location it was thrown.

The documentation for this class was generated from the following file:

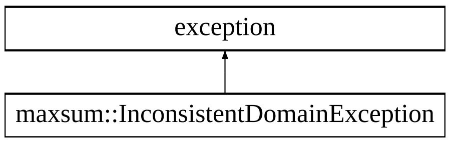
- include/exceptions.h

7.7 maxsum::InconsistentDomainException Class Reference

Exception thrown when variable domains are somehow registered as inconsistent.

`#include <exceptions.h>`

Inheritance diagram for maxsum::InconsistentDomainException:



Public Member Functions

- InconsistentDomainException (const std::string where_, const std::string mesg_) throw ()

  Creates a new expection of this type.
- const char ∗ what () const throw ()

  Returns a message describing the cause of this exception, and the location it was thrown.
- virtual ∼InconsistentDomainException () throw ()

  Destroys this exception and free's its allocated resources.

Protected Attributes

- const std::string where

  String identifying the source code locatioin where this exceptioin was generated.
- const std::string mesg

  Message describing the cause of this exception.

7.7.1 Detailed Description

Exception thrown when variable domains are somehow registered as inconsistent.

7.7.2 Constructor & Destructor Documentation

7.7.2.1 maxsum::InconsistentDomainException::InconsistentDomainException (const std::string *where_*, const std::string *mesg_*) throw () [inline]

Creates a new expection of this type.

Parameters

in	*where_*	the position in the source code where this was generated.
in	*mesg_*	message describing the cause of this exception.

7.7.3 Member Function Documentation

7.7.3.1 const char∗ maxsum::InconsistentDomainException::what ( ) const throw () [inline]

Returns a message describing the cause of this exception, and the location it was thrown.

Returns

a message describing the cause of this exception, and the location it was thrown.

The documentation for this class was generated from the following file:

- include/exceptions.h

7.8 maxsum::util::KeySet< Map > Class Template Reference

Utility class for presenting the keys of a map in a read-only container.

`#include <util_containers.h>`

Classes

- class const_iterator

  Iterator type that allows read-only access to the keys of the underlying map.

Public Types

- typedef Map::key_type value_type

  The type of value contained in this set, which is always equal to the key type of the underlying map.

Public Member Functions

- KeySet (const Map ∗const pKeyMap=0)

  Construct a new maxsum::KeySet backed by a specified map.
- void setMap (const Map ∗const pKeyMap)

  Sets the backend map referenced by this KeySet.
- const_iterator begin () const

  Returns an iterator to the beginning of the key set.
- const_iterator end () const

  Returns an iterator to the end of the key set.
- int size () const

  Returns the size of the underlying map.
- const_iterator find (const value_type &k) const

  Returns an iterator to the specified key, if it is in the map, or KeySet::const_iterator::end if it is not.
- bool contains (const value_type &k) const

  Returns true if the specified key is in this set.

7.8.1 Detailed Description

template<class Map>class maxsum::util::KeySet< Map >

Utility class for presenting the keys of a map in a read-only container.

Provides methods for iterating over this set that adhere to standard library concepts.

Attention

This class is used as part of the implementation of the maxsum::PostOffice class only, and so does not need to be referenced directly by calling libraries. We therefore only implement the subset of the standard container iterface that we actually need for our own purposes.

Template Parameters

Map	the class of underlying map referenced by this object.

7.8.2 Constructor & Destructor Documentation

7.8.2.1 template<class Map> maxsum::util::KeySet< Map >::KeySet (const Map *const *pKeyMap* = 0) [inline]

Construct a new maxsum::KeySet backed by a specified map.

Parameters

in	*pKeyMap*	the backend map whoses key set we wish to present through this class. Changes to keyMap are tracked by this object, but no modificiations can be made to keyMap through this object.

Attention

If pKeyMap is null, then it must be set to point to a valid object using KeySet::setMap before any other member function is called.

Postcondition

*pKeyMap must not be destroyed before this maxsum::KeySet.

7.8.3 Member Function Documentation

7.8.3.1 template<class Map> const_iterator maxsum::util::KeySet< Map >::begin ( ) const [inline]

Returns an iterator to the beginning of the key set.

Returns

an iterator to the beginning of the key set.

7.8.3.2 template<class Map> const_iterator maxsum::util::KeySet< Map >::end ( ) const [inline]

Returns an iterator to the end of the key set.

As in the standard library, the end iterator points one space beyond the last element in the container.

7.8.3.3 template<class Map> const_iterator maxsum::util::KeySet< Map >::find (const value_type & *k*) const [inline]

Returns an iterator to the specified key, if it is in the map, or KeySet::const_iterator::end if it is not.

Returns

an iterator to the specified key, if it is in the map, or KeySet::const_iterator::end if it is not.

7.8.3.4 template<class Map> int maxsum::util::KeySet< Map >::size ( ) const [inline]

Returns the size of the underlying map.

Returns

the size of the underlying map.

The documentation for this class was generated from the following file:

- include/util_containers.h

7.9 maxsum::MaxSumController Class Reference

This class maintains a factor graph and implements the max-sum algorithm.

`#include <MaxSumController.h>`

Public Types

- typedef ValueMap::const_iterator ConstValueIterator

  Read only iterator for all variable value assigments.
- typedef FactorMap::const_iterator ConstFactorIterator

  Read only iterator for all factors.

Public Member Functions

- MaxSumController (int maxIterations=DEFAULT_MAX_ITERATIONS, ValType maxnorm=DEFAULT_MAX-NORM_THRESHOLD)

  Construct a new maxsum::MaxSumController.
- void setFactor (FactorID id, const DiscreteFunction &factor)

  Accessor method for factor function.
- void removeFactor (FactorID id)

  Removes the specified factor from this controller's factor graph.
- void clear ()

  Clear all factors and variables to form an empty factor graph.
- bool hasFactor (FactorID id) const

  Returns true if and only if the specified factor is managed by this maxsum::MaxSumController.
- bool hasEdge (FactorID id, VarID var) const

  Returns true if and only if the specified variable, `var` and factor, `fac` are known to this maxsum::MaxSumController, and `var` is in the domain of `fac`.
- int noFactors () const

  Returns the number of factors know to this factor graph.
- int noVars () const

  Returns the number of variables known to this factor graph.
- int noEdges () const

  Returns the number of edges in the factor graph.
- ConstValueIterator valBegin () const

  Returns a read only iterator to the beginning of the variable value map.
- ConstValueIterator valEnd () const

  Returns a read only iterator to the end of the variable value map.
- ConstFactorIterator factorBegin () const

  Returns a read only iterator to the beginning of the factor map.
- ConstFactorIterator factorEnd () const

  Returns a read only iterator to the end of the factor map.
- const DiscreteFunction & getFactor (FactorID id) const

  Accessor method for factor function.
- bool hasValue (VarID id) const

  Returns true if and only if the specified variable is in the domain of at least one of the factors managed by this maxsum::MaxSumController.
- ValType getValue (VarID id) const

  Returns the current value assigned to the specified variable.
- int optimise ()

  Runs the max-sum algorithm to optimise the values for each variable.

Static Public Attributes

- static const int DEFAULT_MAX_ITERATIONS =100

  Default maximum number of iterations for max-sum algorithm.
- static const ValType DEFAULT_MAXNORM_THRESHOLD =0.0000001

  Default maximum maxnorm allowed between the old and new values of a message, before it is assumed to have converged.

Friends

- std::ostream & operator<< (std::ostream &out, MaxSumController &controller)

  Utility function used to dump the current state of this controller for debugging purposes.

7.9.1 Detailed Description

This class maintains a factor graph and implements the max-sum algorithm.

More specifically, this class implements the max-sum algorithm using the factor graph regime, in which messages are passed along the edges of a factor graph consisting of factor nodes and variable (action) nodes. Once the algorithm has converged, actions selected by maximising over the sum of messages sent to each variable (action) node.

7.9.2 Constructor & Destructor Documentation

7.9.2.1 maxsum::MaxSumController::MaxSumController (int *maxIterations* = DEFAULT_MAX_ITERATIONS, ValType *maxnorm* = DEFAULT_MAXNORM_THRESHOLD) `[inline]`

Construct a new maxsum::MaxSumController.

Parameters

`in`	*maxIterations*	The maximum number of iterations for the max-sum algorithm.
`in`	*maxnorm*	The maximum maxnorm allowed between the old and new values of a message, before it is assumed to have converged.

7.9.3 Member Function Documentation

7.9.3.1 void MaxSumController::clear ( )

Clear all factors and variables to form an empty factor graph.

Postcondition

the state of this maxsum::MaxSumController is reset to that created by the default constructor, with no registered factors or variables.

7.9.3.2 const DiscreteFunction& maxsum::MaxSumController::getFactor (FactorID *id*) const `[inline]`

Accessor method for factor function.

Parameters

`in`	*id*	the unique identifier of the desired factor.

Returns

a reference to the function associated with the factor with unique identifier `id`.

Exceptions

maxsum::NoSuchElement-Exception	if the specified factor is not known to this maxsum::MaxSumController.

7.9.3.3 ValType maxsum::MaxSumController::getValue (VarID *id*) const [inline]

Returns the current value assigned to the specified variable.

This value is only optimised if MaxSumController::optimise has been previously called, and no factor has been modified since it was last called.

Parameters

in	*id*	the unique identifier of the desired variable.

Returns

the current value assigned to the specified variable.

Exceptions

maxsum::NoSuchElement-Exception	if the specified value is not in the domain of any of the factors managed by this maxsum-::MaxSumController.

7.9.3.4 bool maxsum::MaxSumController::hasEdge (FactorID *id,* VarID *var*) const [inline]

Returns true if and only if the specified variable, `var` and factor, `fac` are known to this maxsum::MaxSumController, and `var` is in the domain of `fac`.

Returns

true if and only if the specified variable, `var` and factor, `fac` are known to this maxsum::MaxSumController, and `var` is in the domain of `fac`.

7.9.3.5 bool maxsum::MaxSumController::hasFactor (FactorID *id*) const [inline]

Returns true if and only if the specified factor is managed by this maxsum::MaxSumController.

Returns

true if and only if the specified factor is managed by this maxsum::MaxSumController.

7.9.3.6 bool maxsum::MaxSumController::hasValue (VarID *id*) const [inline]

Returns true if and only if the specified variable is in the domain of at least one of the factors managed by this maxsum::MaxSumController.

Returns

true if and only if the specified variable is in the domain of at least one of the factors managed by this maxsum-::MaxSumController.

7.9.3.7 int MaxSumController::optimise ( )

Runs the max-sum algorithm to optimise the values for each variable.

Postcondition

::getValue(VarID id) will return the optimal value for the the variable with unique identifier `id`.

Returns

the number of max-sum iterations performed.

Postcondition

maxsum::MaxSumController::getValue will return the optimal value for the the variable with unique identifier `id`.

7.9.3.8 void MaxSumController::removeFactor (FactorID *id*)

Removes the specified factor from this controller's factor graph.

In addition, any variables that were previously only connected to this factor, will also be removed from the factor graph. Notice that this does not require the remaining nodes to form a connected graph, but it does mean that variables or factors connect exist in isolation. For example, although every variable and factor must have at least one edge, two variable-factor graph pairs may exist without any edges between the pairs.

Parameters

`in`	*id*	the id of the factor to remove from the graph.

Postcondition

If the specified factor was previously in the factor graph, it will be removed by this function.
Any variables that were previously only connected to this factor, will also be removed from the factor graph.

7.9.3.9 void MaxSumController::setFactor (FactorID *id,* const DiscreteFunction & *factor*)

Accessor method for factor function.

Parameters

`in`	*id*	the unique identifier of the desired factor.
`in`	*factor*	the function representing this factor.

Returns

a reference to the function associated with the factor with unique identifier `id`.

Postcondition

A copy of `factor` is stored internally by this maxsum::MaxSumController and used to form part of a factor graph.
Any previous value of the specified factor is overwritten.

The documentation for this class was generated from the following files:

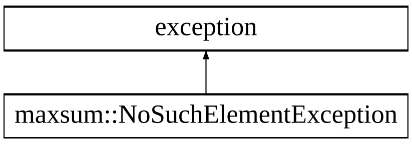
- include/MaxSumController.h
- src/MaxSumController.cpp

7.10 maxsum::NoSuchElementException Class Reference

Exception thrown when there has been an attempt to access an element of a container that does not exist, and cannot be created on demand.

`#include <exceptions.h>`

Inheritance diagram for maxsum::NoSuchElementException:



Public Member Functions

- NoSuchElementException (const std::string where_, const std::string mesg_) throw ()

  Constructs a new exception with specified location and message.
- const char $*$ what () const throw ()

  Returns a message describing the cause of this exception, and the location it was thrown.
- virtual ∼NoSuchElementException () throw ()

  Destroys this exception and free's its allocated resources.

Protected Attributes

- const std::string where

  String identifying the source code locatioin where this exceptioin was generated.
- const std::string mesg

  Message describing the cause of this exception.

7.10.1 Detailed Description

Exception thrown when there has been an attempt to access an element of a container that does not exist, and cannot be created on demand.

7.10.2 Constructor & Destructor Documentation

7.10.2.1 maxsum::NoSuchElementException::NoSuchElementException (const std::string *where_*, const std::string *mesg_*) throw () `[inline]`

Constructs a new exception with specified location and message.

Parameters

in	*where_*	the source code location where this exception was generated.
in	*mesg_*	Message describing the reason for this exception.

7.10.3 Member Function Documentation

7.10.3.1 const char∗ maxsum::NoSuchElementException::what ( ) const throw () [inline]

Returns a message describing the cause of this exception, and the location it was thrown.

Returns

a message describing the cause of this exception, and the location it was thrown.

The documentation for this class was generated from the following file:

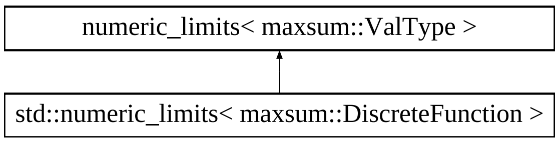
- include/exceptions.h

7.11 std::numeric_limits< maxsum::DiscreteFunction > Class Template Reference

Defines numeric limits for maxsum::DiscreteFunction class.

`#include <DiscreteFunction.h>`

Inheritance diagram for std::numeric_limits< maxsum::DiscreteFunction >:


numeric_limits< maxsum::ValType >
std::numeric_limits< maxsum::DiscreteFunction >

7.11.1 Detailed Description

template<>class std::numeric_limits< maxsum::DiscreteFunction >

Defines numeric limits for maxsum::DiscreteFunction class.

The numeric limits for DiscreteFunctions are inherited from their underlying value type.

The documentation for this class was generated from the following file:

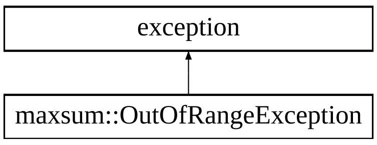
- include/DiscreteFunction.h

7.12 maxsum::OutOfRangeException Class Reference

Exception thrown when indices are out of range.

`#include <exceptions.h>`

Inheritance diagram for maxsum::OutOfRangeException:



Public Member Functions

- OutOfRangeException (const std::string where_, const std::string mesg_) throw ()

  Constructs a new exception with specified location and message.
- const char ∗ what () const throw ()

  Returns a message describing the cause of this exception, and the location it was thrown.
- virtual ∼OutOfRangeException () throw ()

  Destroys this exception and free's its allocated resources.

Protected Attributes

- const std::string where

  String identifying the source code locatioin where this exceptioin was generated.
- const std::string mesg

  Message describing the cause of this exception.

7.12.1 Detailed Description

Exception thrown when indices are out of range.

7.12.2 Constructor & Destructor Documentation

7.12.2.1 maxsum::OutOfRangeException::OutOfRangeException (const std::string *where_*, const std::string *mesg_*) throw () `[inline]`

Constructs a new exception with specified location and message.

Parameters

in	*where_*	the source code location where this exception was generated.
in	*mesg_*	Message describing the reason for this exception.

7.12.3 Member Function Documentation

7.12.3.1 const char∗ maxsum::OutOfRangeException::what ( ) const throw () `[inline]`

Returns a message describing the cause of this exception, and the location it was thrown.

Returns

a message describing the cause of this exception, and the location it was thrown.

The documentation for this class was generated from the following file:

- include/exceptions.h

7.13 maxsum::util::PostOffice< Sender, Receiver, Message > Class Template Reference

Class used to store and manage messages sent between factor graph nodes.

```
#include <PostOffice.h>
```

Public Types

- typedef util::RefMap< Receiver,
  Message * > OutMsgMap

  Map of Receivers to Messages for a specific Sender.
- typedef OutMsgMap::const_iterator OutMsgIt

  Iterator type for PostOffice::OutMsgMap.
- typedef util::RefMap< Sender,
  Message * > InMsgMap

  Map of Senders to Messages for a specific Receivers.
- typedef InMsgMap::const_iterator InMsgIt

  Iterator type for PostOffice::InMsgMap.
- typedef util::KeySet
  < OutboxMap >::const_iterator SenderIt

  Type of iterator returned by PostOffice::senderBegin() and PostOffice::senderEnd().
- typedef util::KeySet< InboxMap >
  ::const_iterator ReceiverIt

  Type of iterator returned by PostOffice::receiverBegin and PostOffice::receiverEnd.

Public Member Functions

- PostOffice ()

  Constructs an empty PostOffice with no edges, senders or receivers.
- void clear ()

  Removes all messages and edges from this postoffice.
- OutMsgMap curOutMsgs (Sender s)

  Returns the current set of output messages for a given sender.
- OutMsgMap prevOutMsgs (Sender s)

  Returns the previous set of output messages for a given sender.
- InMsgMap curInMsgs (Receiver r)

  Returns the current set of input messages for a given receiver.
- InMsgMap prevInMsgs (Receiver r)

  Returns the previous set of input messages for a given receiver.
- bool newMail () const

  Returns true if any receivers have new mail.
- void notify (Receiver r)

  Notifies a receiver that they have new mail.
- void notifyAll ()

  Notifies all receivers that they have new mail.
- int noticeCount () const

  Returns the number of receivers who are currently notified to check their mail.
- Receiver popNotice ()

  Returns the identity of the next receiver who has new mail, and removes their identity from the notification list.
- void swapOutBoxes (Sender s)

  Swaps the current messages from a specified sender with their previous ones.
- void addEdge (Sender s, Receiver r)

  Adds an edge between a specified sender and receiver.
- void addEdge (Sender s, Receiver r, const Message &msgVal)

  Adds an edge between a specified sender and receiver.
- void removeEdge (Sender s, Receiver r)

  Removes an edge between a specified sender and receiver.

- bool hasSender (Sender id) const

  Returns true if a specified sender is registered with this postoffice.
- bool hasReceiver (Receiver id) const

  Returns true if a specified receiver is registered with this postoffice.
- bool hasEdge (Sender s, Receiver r) const

  Returns true if a specified sender and receiver are connected.
- int numOfEdges () const

  Returns the number of edges (routes between sender's and receivers) registered in this PostOffice.
- int numOfSenders () const

  Returns the number of Sender's registered with this PostOffice.
- int numOfReceivers () const

  Returns the number of Receiver's registered with this PostOffice.
- SenderIt senderBegin () const

  Returns iterator to the beginning of the Sender set.
- SenderIt senderEnd () const

  Returns iterator to the beginning of the Sender set.
- ReceiverIt receiverBegin ()

  Returns iterator to the beginning of the Receiver set.
- ReceiverIt receiverEnd ()

  Returns iterator to the beginning of the Receiver set.
- virtual ∼PostOffice ()

  Destructor frees all resources used by this PostOffice.

7.13.1 Detailed Description

template<class Sender, class Receiver, class Message = DiscreteFunction>class maxsum::util::PostOffice< Sender, Receiver, Message >

Class used to store and manage messages sent between factor graph nodes.

Template Parameters

Sender	Type used to uniquely identify message senders, e.g. maxsum::FactorID or maxsum::VarID
Receiver	Type used to uniquely identify message receivers, e.g. maxsum::FactorID or maxsum::VarID
Message	Class used to represent messages which, by default, are maxsum::DiscreteFunction objects.

7.13.2 Member Typedef Documentation

7.13.2.1 template<class Sender , class Receiver , class Message = DiscreteFunction> typedef util::KeySet<InboxMap>::const_iterator maxsum::util::PostOffice< Sender, Receiver, Message >::ReceiverIt

Type of iterator returned by PostOffice::receiverBegin and PostOffice::receiverEnd.

This type of iterator allows read-only access to the set of Receivers registered with this maxsum::PostOffice.

See Also

PostOffice::receiverBegin
PostOffice::receiverEnd

7.13.2.2 template<class Sender , class Receiver , class Message = DiscreteFunction> typedef util::KeySet<OutboxMap>::const_iterator maxsum::util::PostOffice< Sender, Receiver, Message >::SenderIt

Type of iterator returned by PostOffice::senderBegin() and PostOffice::senderEnd().

This type of iterator allows read-only access to the set of Senders registered with this maxsum::PostOffice.

See Also

PostOffice::senderBegin
PostOffice::senderEnd

7.13.3 Constructor & Destructor Documentation

7.13.3.1 template<class Sender , class Receiver , class Message = DiscreteFunction> virtual maxsum::util::PostOffice< Sender, Receiver, Message >::~PostOffice ( ) `[inline]`, `[virtual]`

Destructor frees all resources used by this PostOffice.

Postcondition

Any external pointers to messages managed by this post office will be invalidated.

7.13.4 Member Function Documentation

7.13.4.1 template<class Sender , class Receiver , class Message = DiscreteFunction> void maxsum::util::PostOffice< Sender, Receiver, Message >::addEdge (Sender *s*, Receiver *r*) `[inline]`

Adds an edge between a specified sender and receiver.

Parameters

`in`	*s*	the sender's id
`in`	*r*	the receiver's id

Postcondition

Messages can now be sent from `s` to `s` via this maxsum::PostOffice.

7.13.4.2 template<class Sender , class Receiver , class Message = DiscreteFunction> void maxsum::util::PostOffice< Sender, Receiver, Message >::addEdge (Sender *s*, Receiver *r*, const Message & *msgVal*) `[inline]`

Adds an edge between a specified sender and receiver.

Parameters

`in`	*s*	the sender's id
`in`	*r*	the receiver's id
`in`	*msgVal*	initial value for newly constructed messages.

Postcondition

Messages can now be sent from `s` to `s` via this maxsum::PostOffice.

7.13.4.3 template<class Sender , class Receiver , class Message = DiscreteFunction> InMsgMap maxsum::util::PostOffice< Sender, Receiver, Message >::curInMsgs (Receiver *r*) [inline]

Returns the current set of input messages for a given receiver.

Exceptions

maxsum::UnknownAddress-Exception	if receiver is not registered.

7.13.4.4 template<class Sender , class Receiver , class Message = DiscreteFunction> OutMsgMap maxsum::util::PostOffice< Sender, Receiver, Message >::curOutMsgs (Sender *s*) [inline]

Returns the current set of output messages for a given sender.

Exceptions

maxsum::UnknownAddress-Exception	if sender is not registered.

7.13.4.5 template<class Sender , class Receiver , class Message = DiscreteFunction> bool maxsum::util::PostOffice< Sender, Receiver, Message >::hasEdge (Sender *s*, Receiver *r*) const [inline]

Returns true if a specified sender and receiver are connected.

Parameters

in	*s*	the sender's id
in	*r*	the receiver's id

Returns

true if `s` can send mail to `r` via this maxsum::PostOffice.

7.13.4.6 template<class Sender , class Receiver , class Message = DiscreteFunction> void maxsum::util::PostOffice< Sender, Receiver, Message >::notify (Receiver *r*) [inline]

Notifies a receiver that they have new mail.

Parameters

in	*r*	the receiver to notify

7.13.4.7 template<class Sender , class Receiver , class Message = DiscreteFunction> Receiver maxsum::util::PostOffice< Sender, Receiver, Message >::popNotice ( ) [inline]

Returns the identity of the next receiver who has new mail, and removes their identity from the notification list.

Precondition

PostOffice::newmail returns true
PostOffice::noticeCount returns integer greater than 0.

Postcondition

the size of the notification list is reduced by 1.

Exceptions

maxsum::EmptyNoticeException	if PostOffice::newMail returns false;

7.13.4.8 template<class Sender , class Receiver , class Message = DiscreteFunction> InMsgMap maxsum::util::PostOffice< Sender, Receiver, Message >::prevInMsgs (Receiver *r*) [inline]

Returns the previous set of input messages for a given receiver.

Exceptions

maxsum::UnknownAddressException	if receiver is not registered.

7.13.4.9 template<class Sender , class Receiver , class Message = DiscreteFunction> OutMsgMap maxsum::util::PostOffice< Sender, Receiver, Message >::prevOutMsgs (Sender *s*) [inline]

Returns the previous set of output messages for a given sender.

Exceptions

maxsum::UnknownAddressException	if sender is not registered.

7.13.4.10 template<class Sender , class Receiver , class Message = DiscreteFunction> ReceiverIt maxsum::util::PostOffice< Sender, Receiver, Message >::receiverBegin ( ) [inline]

Returns iterator to the beginning of the Receiver set.

Together with PostOffice::receiverEnd this provides access to the set of all receivers. Example usage:

```
PostOffice<VarID,FactorID> post(...);
...
typedef PostOffice<VarID,FactorID>::ReceiverIt Iterator;
for(Iterator it=post.receiverBegin(); it!=post.receiverEnd(); ++it)
{
   std::cout << "Receiver " << *it << " is registered.\n";
}
```

See Also

PostOffice::receiverEnd

7.13.4.11 template<class Sender , class Receiver , class Message = DiscreteFunction> ReceiverIt maxsum::util::PostOffice< Sender, Receiver, Message >::receiverEnd ( ) [inline]

Returns iterator to the beginning of the Receiver set.

Together with PostOffice::receiverBegin this provides access to the set of all receivers. Example usage:

```
PostOffice<VarID,FactorID> post(...);
...
typedef PostOffice<VarID,FactorID>::ReceiverIt Iterator;
for(Iterator it=post.receiverBegin(); it!=post.receiverEnd(); ++it)
{
   std::cout << "Receiver " << *it << " is registered.\n";
}
```

See Also

PostOffice::receiverBegin

7.13.4.12 template<class Sender , class Receiver , class Message = DiscreteFunction> void **maxsum::util::PostOffice< Sender, Receiver, Message >::removeEdge (Sender *s*, Receiver *r*)** [inline]

Removes an edge between a specified sender and receiver.

Parameters

in	*s*	the sender's id
in	*r*	the receiver's id

Postcondition

Messages will no longer be sent from `s` to `s` via this maxsum::PostOffice.

7.13.4.13 template<class Sender , class Receiver , class Message = DiscreteFunction> SenderIt **maxsum::util::PostOffice< Sender, Receiver, Message >::senderBegin ( ) const** [inline]

Returns iterator to the beginning of the Sender set.

Together with PostOffice::senderEnd this provides access to the set of all senders. Example usage:

```
PostOffice<VarID,FactorID> post(...);
...
typedef PostOffice<VarID,FactorID>::SenderIt Iterator;
for(Iterator it=post.senderBegin(); it!=post.senderEnd(); ++it)
{
   std::cout << "Sender " << *it << " is registered.\n";
}
```

See Also

PostOffice::senderEnd

7.13.4.14 template<class Sender , class Receiver , class Message = DiscreteFunction> SenderIt **maxsum::util::PostOffice< Sender, Receiver, Message >::senderEnd ( ) const** [inline]

Returns iterator to the beginning of the Sender set.

Together with PostOffice::senderBegin this provides access to the set of all senders. Example usage:

```
PostOffice<VarID,FactorID> post(...);
...
typedef PostOffice<VarID,FactorID>::SenderIt Iterator;
for(Iterator it=post.senderBegin(); it!=post.senderEnd(); ++it)
```

```
{
   std::cout << "Sender " << *it << " is registered.\n";
}
```

See Also

PostOffice::senderBegin

7.13.4.15 template<class Sender , class Receiver , class Message = DiscreteFunction> void maxsum::util::PostOffice< Sender, Receiver, Message >::swapOutBoxes (Sender *s*) [inline]

Swaps the current messages from a specified sender with their previous ones.

This allows the previous messages to be overwritten with new messages, without having to free of allocate temporary objects.

The documentation for this class was generated from the following file:

- include/PostOffice.h

7.14 maxsum::util::RefMap< Key, Val > Class Template Reference

This class provides a read only wrapper around an existing map, such as that provided by std::map.

`#include <util_containers.h>`

Public Types

- typedef std::map< Key, Val > PtrMap

    Type of map used to store value pointers.
- typedef PtrMap::const_iterator const_iterator

    Iterator type returned by this map.
- typedef PtrMap::value_type value_type

    Key-Value pair type stored by this map.
- typedef PtrMap::value_type key_type

    Key type used to index this map.
- typedef PtrMap::mapped_type mapped_type

    Value type stored by this map.

Public Member Functions

- RefMap (const PtrMap &map)

    Constructs an empty map.
- const_iterator begin () const

    Returns an iterator the first element in this map.
- const_iterator end () const

    Returns an iterator to the next position after the last element of this map.
- const Val & operator[] (Key key) const

    Provides a constant reference to the value pointed to by key, or throws an exception is the key is not currently mapped to any value.
- const_iterator find (Key key) const

    Tries to find the value for a given key in this map.
- int size () const

    Returns the number of elements in this map.

7.14.1 Detailed Description

template<class Key, class Val>class maxsum::util::RefMap< Key, Val >

This class provides a read only wrapper around an existing map, such as that provided by std::map.

In particular, this class provides a const implementation of the [] operator, which throws an exception if the requested key is not already in the underlying map, rather than trying to insert it. This functionality is not provided by the standard library.

Note: Currently, we only implement that subset of the map iterface that we actually require for our purposes.

Attention

This class is used as part of the implementation of the maxsum::PostOffice class only, and so does not need to be referenced directly by calling libraries. We therefore only implement the subset of the standard container iterface that we actually need for our own purposes.

Template Parameters

Key	Type of key used by this map.
Val	Type of value referenced by this map. Internally, the map stores pointers to Val objects, rather than the Val objects themselves, but presents the same interface as a std::map that does store them.

7.14.2 Member Function Documentation

7.14.2.1 template<class Key , class Val > const_iterator maxsum::util::RefMap< Key, Val >::begin ( ) const `[inline]`

Returns an iterator the first element in this map.

This iterator provides readonly access to the elements of this map.

7.14.2.2 template<class Key , class Val > const_iterator maxsum::util::RefMap< Key, Val >::end ( ) const `[inline]`

Returns an iterator to the next position after the last element of this map.

See C++ standard library documentation for rationale.

7.14.2.3 template<class Key , class Val > const Val& maxsum::util::RefMap< Key, Val >::operator[] (Key *key*) const `[inline]`

Provides a constant reference to the value pointed to by key, or throws an exception is the key is not currently mapped to any value.

Attention

This is intentionally different from the behaviour of std::map::operator[], because we only want to provide read-access through this operator.

Parameters

`in`	*key*	the key whoses value we want to return.

Exceptions

NoSuchElementException	if key is not currently in this map.

Returns

a constant reference to the mapped value.

The documentation for this class was generated from the following file:

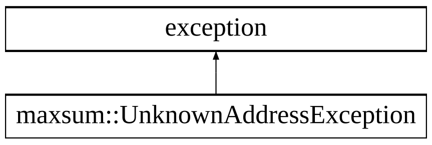
- include/util_containers.h

7.15 maxsum::UnknownAddressException Class Reference

Exception thrown when a maxsum::util::PostOffice does not recognise the ID of a Sender or Receiver.

```
#include <exceptions.h>
```

Inheritance diagram for maxsum::UnknownAddressException:



Public Member Functions

- UnknownAddressException (const std::string where_, const std::string mesg_) throw ()

  Constructs a new exception with specified location and message.
- const char $*$ what () const throw ()

  Returns a message describing the cause of this exception, and the location it was thrown.
- virtual ∼UnknownAddressException () throw ()

  Destroys this exception and free's its allocated resources.

Protected Attributes

- const std::string where

  String identifying the source code locatioin where this exceptioin was generated.
- const std::string mesg

  Message describing the cause of this exception.

7.15.1 Detailed Description

Exception thrown when a maxsum::util::PostOffice does not recognise the ID of a Sender or Receiver.

7.15.2 Constructor & Destructor Documentation

7.15.2.1 maxsum::UnknownAddressException::UnknownAddressException (const std::string *where_*, const std::string *mesg_*) throw () [inline]

Constructs a new exception with specified location and message.

Parameters

`in`	*where_*	the source code location where this exception was generated.
`in`	*mesg_*	Message describing the reason for this exception.

7.15.3 Member Function Documentation

7.15.3.1 const char∗ maxsum::UnknownAddressException::what ( ) const throw () `[inline]`

Returns a message describing the cause of this exception, and the location it was thrown.

Returns

a message describing the cause of this exception, and the location it was thrown.

The documentation for this class was generated from the following file:

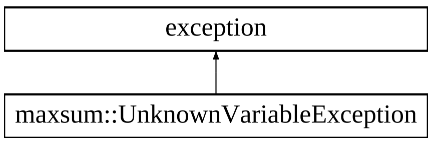
- include/exceptions.h

7.16 maxsum::UnknownVariableException Class Reference

Exception thrown when a variable is referred to, but has not yet been registered using either maxsum::registerVariable or maxsum::registerVariables.

`#include <exceptions.h>`

Inheritance diagram for maxsum::UnknownVariableException:



Public Member Functions

- UnknownVariableException (const std::string where_, const std::string mesg_) throw ()
  Creates a new expection of this type.
- const char ∗ what () const throw ()
  Returns a message describing the cause of this exception, and the location it was thrown.
- virtual ∼UnknownVariableException () throw ()
  Destroys this exception and free's its allocated resources.

Protected Attributes

- const std::string where
  String identifying the source code locatioin where this exceptioin was generated.
- const std::string mesg
  Message describing the cause of this exception.

7.16.1 Detailed Description

Exception thrown when a variable is referred to, but has not yet been registered using either maxsum::registerVariable or maxsum::registerVariables.

7.16.2 Constructor & Destructor Documentation

7.16.2.1 maxsum::UnknownVariableException::UnknownVariableException (const std::string *where_*, const std::string *mesg_*) throw () `[inline]`

Creates a new expection of this type.

Parameters

`in`	*where_*	the position in the source code where this was generated.
`in`	*mesg_*	message describing the cause of this exception.

7.16.3 Member Function Documentation

7.16.3.1 const char∗ maxsum::UnknownVariableException::what ( ) const throw () `[inline]`

Returns a message describing the cause of this exception, and the location it was thrown.

Returns

a message describing the cause of this exception, and the location it was thrown.

The documentation for this class was generated from the following file:

- include/exceptions.h

Chapter 8

File Documentation

8.1 include/common.h File Reference

Common types and functions used by Max-Sum library.

```
#include <cfloat>
#include <string>
#include <vector>
#include "exceptions.h"
```

Namespaces

- namespace maxsum

  Namespace for all public types and functions defined by the Max-Sum library.

Typedefs

- typedef double maxsum::ValType

  Type of values stored by maxsum::DiscreteFunction objects.
- typedef unsigned int maxsum::VarID

  Type used for uniquely identifying variables.
- typedef unsigned int maxsum::FactorID

  Type used for uniquely identifying factors in a factor graph.
- typedef int maxsum::ValIndex

  Integer type used for indexing coefficient values.

Functions

- template<class VecType >
  void maxsum::ind2sub (const VecType &siz, const typename VecType::value_type ind, VecType &sub)

  C++ Implementation of Matlab ind2sub function.
- template<class SizIt , class SubIt >
  ValIndex maxsum::sub2ind (SizIt sizFirst, SizIt sizEnd, SubIt subFirst, SubIt subEnd)

  C++ Implementation of Matlab sub2ind function.
- template<class VecType >
  VecType::value_type maxsum::sub2ind (const VecType &siz, const VecType &sub)

  C++ Implementation of Matlab sub2ind function.

Variables

- const ValType maxsum::DEFAULT_VALUE_TOLERANCE = DBL_EPSILON ∗ 1000.0

  Default tolerance used for comparing values of type maxsum::ValType.

8.1.1 Detailed Description

Common types and functions used by Max-Sum library. In particular, this file defines common typedefs, and functions for calculating subindices and linear indices for referencing the contents of N-D arrays. These resemble similar functions defined in the Matlab environment.

Author

Luke Teacy

8.2 include/DiscreteFunction.h File Reference

Defines the maxsum::DiscreteFunction class and related utility functions.

```
#include <cmath>
#include <iostream>
#include <cassert>
#include <algorithm>
#include "common.h"
#include "register.h"
#include "DomainIterator.h"
```

Classes

- class maxsum::DiscreteFunction

  Class representing functions of sets of variables with discrete domains.
- class std::numeric_limits< maxsum::DiscreteFunction >

  Defines numeric limits for maxsum::DiscreteFunction class.

Namespaces

- namespace maxsum

  Namespace for all public types and functions defined by the Max-Sum library.

Typedefs

- typedef ValType(∗ maxsum::UnaryScalarOp)(const ValType)

  Function type for operations applied to function values.
- typedef ValType(∗ maxsum::DualScalarOp)(const ValType, const ValType)

  Function type for operations applied to two functions.

Functions

- std::ostream & maxsum::operator<< (std::ostream &out, const DiscreteFunction &fun)

  Pretty prints a maxsum::DiscreteFunction Format is similar to the disp function in Matlab for N-D arrays, except that first dimension appears in rows rather than columns.

- bool maxsum::sameDomain (const DiscreteFunction &f1, const DiscreteFunction &f2)

  Check that two maxsum::DiscreteFunction objects have the same domain.
- bool maxsum::equalWithinTolerance (const DiscreteFunction &f1, const DiscreteFunction &f2, ValType tol=D-EFAULT_VALUE_TOLERANCE)

  Check that two maxsum::DiscreteFunction objects are equal within a specified tolerance.
- bool maxsum::strictlyEqualWithinTolerance (const DiscreteFunction &f1, const DiscreteFunction &f2, ValType tol=DEFAULT_VALUE_TOLERANCE)

  Check that two maxsum::DiscreteFunction objects are equal with a specified tolerance, and have exactly the same domain.
- bool maxsum::operator== (const DiscreteFunction &f1, const DiscreteFunction &f2)

  Return true if functions are equal.
- bool maxsum::operator!= (const DiscreteFunction &f1, const DiscreteFunction &f2)

  Return true if functions are equal.
- DiscreteFunction maxsum::operator/ (const ValType f1, const DiscreteFunction &f2)

  Peforms element-wise division of a scalar by a function.
- DiscreteFunction maxsum::operator∗ (const ValType f1, const DiscreteFunction &f2)

  Peforms element-wise multiplication of a scalar by a function.
- DiscreteFunction maxsum::operator+ (const ValType f1, const DiscreteFunction &f2)

  Peforms element-wise addition of a scalar by a function.
- DiscreteFunction maxsum::operator- (const ValType f1, const DiscreteFunction &f2)

  Peforms element-wise subtraction of a function from a scalar.
- template<class VarIt , class IndIt >
  void maxsum::condition (const DiscreteFunction &inFun, DiscreteFunction &outFun, VarIt vBegin, VarIt vEnd, IndIt iBegin, IndIt iEnd)

  Condition function on specified variable values.
- template<class VarMap >
  void maxsum::condition (const DiscreteFunction &inFun, DiscreteFunction &outFun, VarMap vars)

  Condition function on specified variable values.
- template<typename F >
  void maxsum::marginal (const DiscreteFunction &inFun, F aggregate, DiscreteFunction &outFun)

  Marginalise a maxsum::DiscreteFunction using a specified aggregation function.
- void maxsum::maxMarginal (const DiscreteFunction &inFun, DiscreteFunction &outFun)

  Marginalise a maxsum::DiscreteFunction by maximisation.
- void maxsum::minMarginal (const DiscreteFunction &inFun, DiscreteFunction &outFun)

  Marginalise a maxsum::DiscreteFunction by minimisation.
- void maxsum::meanMarginal (const DiscreteFunction &inFun, DiscreteFunction &outFun)

  Marginalise a maxsum::DiscreteFunction by averaging.
- template<UnaryScalarOp OP>
  DiscreteFunction maxsum::elementWiseOp (const DiscreteFunction &inFcn)

  Template used to generate operations that apply some function to each of a DiscreteFunction's values.
- template<DualScalarOp OP>
  DiscreteFunction maxsum::elementWiseOp (const DiscreteFunction &inFcn1, const DiscreteFunction &in-Fcn2)

  Template used to generate operations that apply some operation to a pair of DiscreteFunctions.
- maxsum::DiscreteFunction **std::log** (const maxsum::DiscreteFunction &fcn)

  Returns the elementwise log of a function.
- maxsum::DiscreteFunction **std::cos** (const maxsum::DiscreteFunction &fcn)

  Returns the elementwise cosine value of a function.
- maxsum::DiscreteFunction **std::sin** (const maxsum::DiscreteFunction &fcn)

  Returns the elementwise sine value of a function.
- maxsum::DiscreteFunction **std::tan** (const maxsum::DiscreteFunction &fcn)

  Returns the elementwise tangent value of a function.

- maxsum::DiscreteFunction **std::fabs** (const maxsum::DiscreteFunction &fcn)

  Returns the elementwise absolute value of a function.
- maxsum::DiscreteFunction **std::abs** (const maxsum::DiscreteFunction &fcn)

  Returns the elementwise absolute value of a function.
- maxsum::DiscreteFunction **std::exp** (const maxsum::DiscreteFunction &fcn)

  Returns the elementwise exponent of a function.
- maxsum::DiscreteFunction **std::sqrt** (const maxsum::DiscreteFunction &fcn)

  Returns the elementwise square root of a function.
- maxsum::DiscreteFunction **std::ceil** (const maxsum::DiscreteFunction &fcn)

  Returns the elementwise ceil value of a function.
- maxsum::DiscreteFunction **std::floor** (const maxsum::DiscreteFunction &fcn)

  Returns the elementwise floor value of a function.
- maxsum::DiscreteFunction **std::pow** (const maxsum::DiscreteFunction &base, const maxsum::DiscreteFunction &exp)

  Takes one function to the power of another.

8.2.1 Detailed Description

Defines the maxsum::DiscreteFunction class and related utility functions.

8.3 include/DomainIterator.h File Reference

This file defines the maxsum::DomainIterator class.

```
#include <algorithm>
#include <vector>
#include "common.h"
#include "register.h"
```

Classes

- class maxsum::DomainIterator

  This class provides methods for iterating over the Cartesian product for a set of variable domains.

Namespaces

- namespace maxsum

  Namespace for all public types and functions defined by the Max-Sum library.

8.3.1 Detailed Description

This file defines the maxsum::DomainIterator class. The maxsum::DomainIterator class provides methods for iterating over the Cartesian product for a set of variable domains.

8.4 include/exceptions.h File Reference

Defines exception classes for all error conditions that may occur in the maxsum library.

```
#include <string>
#include <exception>
```

Classes

- class maxsum::NoSuchElementException

  Exception thrown when there has been an attempt to access an element of a container that does not exist, and cannot be created on demand.
- class maxsum::EmptyNoticeException

  Exception thrown by maxsum::util::PostOffice::popNotice when there are no active notices.
- class maxsum::UnknownAddressException

  Exception thrown when a maxsum::util::PostOffice does not recognise the ID of a Sender or Receiver.
- class maxsum::BadDomainException

  Exception thrown when subindices are incorrectly specified for a maxsum::DiscreteFunction.
- class maxsum::OutOfRangeException

  Exception thrown when indices are out of range.
- class maxsum::DomainConflictException

  Exception thrown when conflicting domains are specified for a variable.
- class maxsum::UnknownVariableException

  Exception thrown when a variable is referred to, but has not yet been registered using either maxsum::registerVariable or maxsum::registerVariables.
- class maxsum::InconsistentDomainException

  Exception thrown when variable domains are somehow registered as inconsistent.

Namespaces

- namespace maxsum

  Namespace for all public types and functions defined by the Max-Sum library.

8.4.1 Detailed Description

Defines exception classes for all error conditions that may occur in the maxsum library.

Author

Luke Teacy

8.5 include/mainpage.h File Reference

This header defines the main page for this documentation, and is for that purpose only.

Namespaces

- namespace maxsum

  Namespace for all public types and functions defined by the Max-Sum library.

8.5.1 Detailed Description

This header defines the main page for this documentation, and is for that purpose only.

Author

Dr W. T. Luke Teacy, University of Southampton

8.6 include/MaxSumController.h File Reference

Defines the MaxSumController class, which implements the max-sum algorithm.

```
#include <iostream>
#include <map>
#include <stack>
#include "common.h"
#include "DiscreteFunction.h"
#include "PostOffice.h"
```

Classes

- class maxsum::MaxSumController

  This class maintains a factor graph and implements the max-sum algorithm.

Namespaces

- namespace maxsum

  Namespace for all public types and functions defined by the Max-Sum library.

Functions

- std::ostream & maxsum::operator<< (std::ostream &out, MaxSumController &controller)

  Utility function used to dump the current state of this controller for debugging purposes.

8.6.1 Detailed Description

Defines the MaxSumController class, which implements the max-sum algorithm.

Author

W. T. Luke Teacy - University of Southampton

8.7 include/PostOffice.h File Reference

This file defines the utility maxsum::PostOffice class.

```
#include <map>
#include <set>
#include <queue>
#include "DiscreteFunction.h"
#include "util_containers.h"
```

Classes

- class maxsum::util::PostOffice< Sender, Receiver, Message >

  Class used to store and manage messages sent between factor graph nodes.

Namespaces

- namespace maxsum

  Namespace for all public types and functions defined by the Max-Sum library.
- namespace maxsum::util

  Utility namespace for types used for maxsum library implementation.

Typedefs

- typedef PostOffice< VarID,
  FactorID > maxsum::util::V2FPostOffice

  Convenience typedef for Variable to Factor PostOffices.
- typedef PostOffice< FactorID,
  VarID > maxsum::util::F2VPostOffice

  Convenience typedef for Factor to Variable PostOffices.
- typedef PostOffice< FactorID,
  FactorID > maxsum::util::F2FPostOffice

  Convenience typedef for Factor to Factor PostOffices.

8.7.1 Detailed Description

This file defines the utility maxsum::PostOffice class.

8.8 include/register.h File Reference

This Header defines functions for registering the set of all variables on which maxsum::DiscreteFunction objects may depend.

```
#include "common.h"
```

Namespaces

- namespace maxsum

  Namespace for all public types and functions defined by the Max-Sum library.

Functions

- bool maxsum::isRegistered (VarID var)

  Returns true if the specified variable is registered.
- template<class VarIt >
  bool maxsum::allRegistered (VarIt varBegin, VarIt varEnd)

  Returns true if all specified variables are registered.
- ValIndex maxsum::getDomainSize (VarID var)

  Returns the registered domain size for a specified variable.

- int maxsum::getNumOfRegisteredVariables ()

    Returns the number of currently registered variables.
- void maxsum::registerVariable (VarID var, ValIndex siz)

    Registers a variable with a specified domain size.
- template<class VarIt , class IndIt >
  void maxsum::registerVariables (VarIt varBegin, VarIt varEnd, IndIt sizBegin, IndIt sizEnd)

    Register a list of variables with specified domain sizes.

8.8.1 Detailed Description

This Header defines functions for registering the set of all variables on which maxsum::DiscreteFunction objects may depend. Variables are uniquely identified by a key of type maxsum::VarID and each as a specified domain size. The purpose of the functions defined in this file are to register the domain size for each variable before it is used, and ensure that this size remains fixed throughout a programs execution. Variables can be registered multiple times, but in each case the domain size must not change. Variables must always be registered before they are referenced by any function.

8.9 include/util_containers.h File Reference

This file defines some utility container types required for the implementation of the maxsum library.

```
#include <cassert>
#include <map>
```

Classes

- class maxsum::util::KeySet< Map >

    Utility class for presenting the keys of a map in a read-only container.
- class maxsum::util::KeySet< Map >::const_iterator

    Iterator type that allows read-only access to the keys of the underlying map.
- class maxsum::util::RefMap< Key, Val >

    This class provides a read only wrapper around an existing map, such as that provided by std::map.

Namespaces

- namespace maxsum

    Namespace for all public types and functions defined by the Max-Sum library.
- namespace maxsum::util

    Utility namespace for types used for maxsum library implementation.

8.9.1 Detailed Description

This file defines some utility container types required for the implementation of the maxsum library.

Attention

The types defined in this header are not intended to form part of the public interface to the maxsum library. Knowledge of these types is therefore not required for interfacing with the library.

8.10 src/DiscreteFunction.cpp File Reference

Implementation of member functions of class maxsum::DiscreteFunction.

```
#include <cmath>
#include <vector>
#include <cstdarg>
#include <algorithm>
#include <iostream>
#include "DiscreteFunction.h"
#include "DomainIterator.h"
```

8.10.1 Detailed Description

Implementation of member functions of class maxsum::DiscreteFunction.

8.11 src/DomainIterator.cpp File Reference

This file implments the maxsum::DomainIterator class.

```
#include "register.h"
#include "DomainIterator.h"
#include "DiscreteFunction.h"
```

8.11.1 Detailed Description

This file implments the maxsum::DomainIterator class. The maxsum::DomainIterator class provides methods for iterating over the Cartesian product for a set of variable domains.

8.12 src/MaxSumController.cpp File Reference

Implementation of MaxSumController class members.

```
#include "MaxSumController.h"
#include <iostream>
```

8.12.1 Detailed Description

Implementation of MaxSumController class members.

See Also

MaxSumController.h

Author

W. T. Luke Teacy - University of Southampton

8.13 src/register.cpp File Reference

Implementation of functions in register.h.

```
#include <map>
#include <string>
#include <sstream>
#include "register.h"
```

8.13.1 Detailed Description

Implementation of functions in register.h.

See Also

register.h

Author

Luke Teacy

Index